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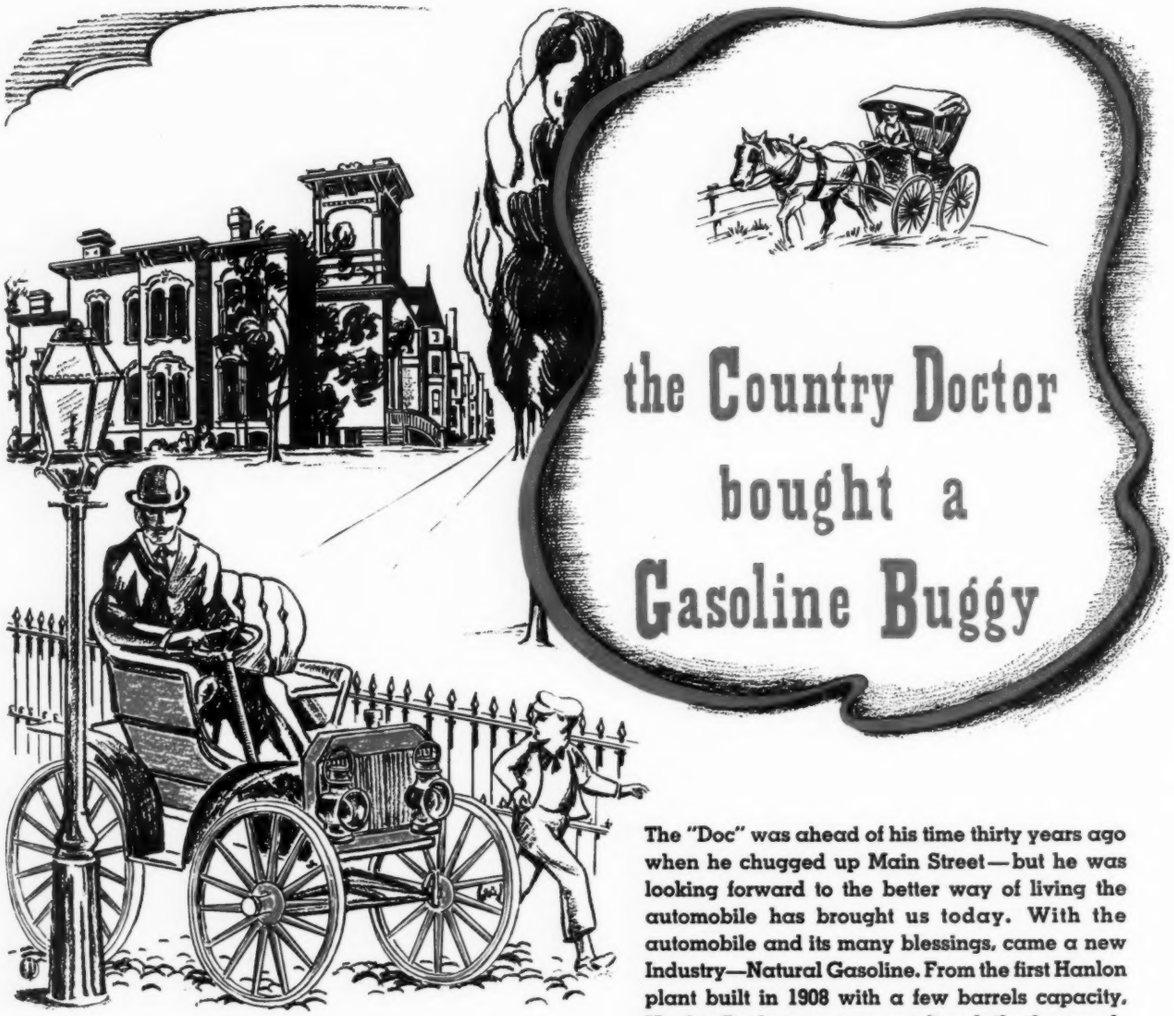

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VOLUME 11 **OCTOBER 1940** **NUMBER 10**

WORLD PETROLEUM: Incorporating Petroleum Equipment Exporter

CORRESPONDENCE

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SUBSCRIPTIONS

Annual subscription to World Petroleum is offered at the flat rate of five dollars (U. S.) postpaid to any country in the International Postal Union.

For the convenience of subscribers the publisher will accept payment in any of the following currencies at the fixed rate shown below:

Argentina	16 paper dollars
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Remittances or drafts should be drawn to the order of the Publisher, World Petroleum, payable in New York and London.

Subscriber's name and address should be in Roman capitals on the subscription order.

Official position of subscriber is requested.

Advance notice, if possible, of a change of subscriber's address should be given.

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AGENCIES

Single copies of World Petroleum are obtainable every month, within the delay imposed by the international mail service, at any of the following agencies:

Maracaibo, Venezuela—High Life Tailors.
The Hague, Netherlands—Martinus Nijhoff, Lange Voorhout 9
London—World Petroleum, 3 Savoy Pl., Victoria Embankment, W.C.2, telephone: TEMple Bar 1735
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New York—Telephone Rector 2-2043 for list of 20 newsstands carrying copies
Paris—Librarie Brentano, 37 Avenue de l'Opera.
Port of Spain, Trinidad—Davidson & Todd, Ltd., 8 Frederick St.
Los Angeles—412 West 6th St., telephone: Mutual 1391.

British subscribers may make payments at the London office of World Petroleum. Monthly copies, two shillings; yearly, one guinea.

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Fluor cooling tower at Huntington Beach, California

EDITORIAL

SPEAKING OF BACKSTABBING

ATTORNEY General Jackson has announced that the much bruited suit against twenty-two large oil companies is to go forward. It is to be based on charges of conspiracy to restrict crude production, to hold down crude prices and to maintain unduly high sales rates for petroleum products. It also alleges discrimination in the operation of transportation facilities and marketing outlets.

The action in this form differs greatly from the widely advertised advance notices of its original objectives. These statements proclaimed that the case, which had been in course of preparation for more than two years under the immediate direction of Assistant Attorney General Thurman Arnold, was to be the grand climacteric of the series of prosecutions directed against the oil industry for the past several years. It was to eviscerate the oil companies, to amputate their pipe lines and tankships, their bulk terminals and marketing outlets. Staged in the midst of a presidential campaign when full opportunity existed for turning to the political advantage of the administration the anti-business prejudice to which it has constantly appealed it was to end the constructive progress made by the industry in the past thirty years and return it to the operating methods that existed in the derided horse and buggy days. Incidentally it was expected to establish Mr. Arnold as the champion trust buster of all time.

This spectacular program was put into temporary eclipse when the Advisory Commission for National Defense pointed out that it would seriously impair the carrying out of plans already adopted by the Army and Navy for utilizing the resources of the oil industry in the national preparedness effort. While disavowing any purpose to interfere with the enforcement of laws against price fixing or other restraints on competition the Commission felt in duty bound to call attention to the effect upon national defense of breaking up the established organization of the oil companies which it described as "well adapted to the defense program". It mentioned specifically the arrangements made for construction by the companies of new pipe lines and terminals for the use of the armed forces and pointed out that to prohibit the exchange of products between companies not only would upset defense measures that had been decided upon but would increase the cost of oil products to the government.

While deferring to the Commission's views the Attorney General at the same time addressed a letter to Senator Gillette, who months ago had sponsored a bill to force dismemberment of oil companies, in which he urged the Senator not to let the pendency of litigation deter him from pushing the adoption of the legislation he had been urging.

This places the head of the Department of Justice in the position of acknowledging that the disintegration of the oil companies at this time would create serious problems for the national defense but being perfectly willing to encourage Congress to erect permanent obstacles of the very same nature. This attitude of facing both ways unfortunately is not confined to one department but crops up repeatedly in Washington where admonitions to push national defense measures with all possible speed are accompanied by the ignoring of or insistence upon barriers that make rapid progress impossible.

The reputed offer of a supervising federal agency as an alternative to Court attack may not be true, but it is not unfair to say, especially as the name of Secretary Ickes was linked with it, that it is not inconsistent with repeated efforts of the administration in the past, sometimes by prosecutions, sometimes by persuasion and sometimes by inspired legislation, to bring the oil industry under the paralyzing hand of federal control.

Looking into the record of the past seven years it is perhaps not surprising that the very time when the oil industry is being called upon to bend all its resources to the sadly belated task of national preparedness should be selected to assail the companies that can be most helpful in this work with a costly, time-consuming prosecution and to encourage legislation directed against their efficient operation.

Administration's Oil Suit Collides With National Defense Program

WHILE the spectacle of different bureaus or departments of the federal administration following diametrically opposed and mutually destructive policies has been repeated many times in Washington during the past seven years, no more striking example of it has occurred than the course recently followed in relation to the oil industry.

When the Advisory Commission for National Defense was established, one of the subjects to which it directed early attention was that of their country's oil supply. In view of the vital importance of oil in modern warfare the necessity was recognized of providing adequate supplies of aviation gasoline, fuel for ships, tanks and trucks, and of developing the possibilities of petroleum in the supply of explosives and other war materials. Members of the oil industry were summoned to Washington and the task of marshalling its full resources to serve the great national preparedness effort was pushed forward with the enthusiastic support of the entire industry.

In the midst of this activity, the Department of Justice announced that it was about to proceed with the greatest of its oil industry prosecutions, an anti-trust action against twenty-two companies, including the largest ones in the business. This was no ordinary suit, but an intensive drive intended to smash these integrated companies by forcing them to give up their pipe lines, tankers and other means of transportation and to divest themselves of their marketing outlets, including bulk plants, storage facilities and service stations.

This move by the Attorney General was the result of no sudden decision. The suit had been in preparation for a matter of two years or more. Whatever other factors led to its being brought just ahead of the presidential election it could not be alleged that the defense campaign had any influence in causing it to be sprung at this time. However, the disastrous effect of breaking up the country's leading oil companies and crippling their facilities at a time when the fullest coordination of effort was called for was so obvious that the Defense Commission, although it had no authority in the matter, was moved to intervene.

This it did in the most polite way by asking the Attorney General to defer action until it could study the effect of the suit upon the national defense program. Under the circumstances, the officials of the Department of Justice could hardly refuse so moderate a request and Attorney General Jackson announced that the filing of the suit would be delayed pending the preparation of the report. He was careful to state that there was no commitment to drop the suit or to do more than defer action for the short time needed by the Defense Commission to prepare its statement.

The report of the Commission was made public September 19th. Though couched in restrained and deferential language, it blasts the proposal for disintegration of the oil companies on half a dozen fundamental considerations and shows that it would disrupt plans of the Army and Navy for provision of their emergency requirements of petroleum products.

The full report of the commission follows:

The Advisory Commission to the Council of National Defense has given consideration to the proposed anti-trust suit against the American Petroleum Institute and twenty-two major oil companies, their subsidiaries and affiliates, with a view to determining its probable effect on the defense program.

The Commission appreciates that the

Advisory Commission's Report Declares Existing Structure of Industry Well Adapted to Defense Needs and Shows That Breaking Up of Companies Would Disrupt Army and Navy Plans for Providing Needed Supplies.

decision of whether or not to take action against any particular persons or corporations for violation of the anti-trust laws must be made by the Attorney General in the exercise of his sound discretion. It further appreciates that in the work of the Department of Justice generally, and in the interpretation of the anti-trust laws and the institution of civil proceedings thereunder in particular, there are involved not only problems of law but also problems of policy, including the harmonization of other aims and purposes of the nation. This report is submitted in the belief that it will be of assistance with respect to the questions of policy presented.

The Commission's primary function is to assure and facilitate the availability of adequate supplies of all materials necessary for the defense of the nation at the lowest cost consistent with other necessary objectives. The Commission, therefore, would deplore any condition or action leading to a failure of supply of such materials, whether for a short or long time, and whether partial or complete, or leading, among other things, to a lessening of efficiency, waste of natural resources, or any substantial increase in price to the Government or to consumers.

In appraising the impact of the proposed suit on the defense program the Commission has examined the relief prayed for in the complaint and considered the effect of such relief upon the technical task of supplying petroleum products so vital to our defense forces and industry. Emphasis has been placed upon the anticipated effects of granting the prayer for relief, rather than upon the anticipated effects of filing the proposed complaint, largely because the practical result of the suit can be tested only by the objectives of the Department as stated in its complaint. It is impossible, moreover, to say with assurance how long the trial of the issues raised by the complaint will require, how soon the structural changes sought will be achieved, or even what the character of the defense program will be during that interim period. If the objectives of the suit are consistent with the interests of national defense, no question can be raised by this Commission. Our task is simply to determine so far as practicable whether those objectives in fact substantially impede the defense program.

The Commission states at the outset that, in view of its desire to insure and facilitate adequate supplies at lowest cost, it is opposed to monopolistic or conspiratorial price-fixing and to artificial restrictions on supply of materials (except where restrictions on supply are temporarily necessary to promote sound conservation of the nation's resources under law). Such price fixing and restrictions, always a threat to the national welfare, are particularly dangerous in time of emergency. The Commission does not have information adequate to justify comment upon the various allegations in the draft complaint relating to price fixing and similar abuses in the wholesale and retail distribution of petroleum and petroleum products. But the Commission wishes to assure the Attorney General that it will wholeheartedly approve any appropriate legal action brought to eliminate such restraints on competition, where they are proven to exist.

The other provisions in the draft complaint, primarily the prayer that twenty-two of the larger integrated oil companies, their subsidiaries and affiliates, be required to divest themselves of their transportation and their marketing facilities, require thorough consideration from the defense viewpoint.

Before considering the effect of such a prayer, we may point out, although we do not propose to emphasize, that the suit has its intangible aspects. Certain demands have been made and others will be made upon the

petroleum industry in connection with the defense program. From this industry, and from industry generally, the Government expects cooperation, and indeed enthusiasm, in furthering the defense effort. The Commission is loath to believe that the members of the industry, or the members of any other industry, would consciously permit any personal resentment to interfere with the vital purchasing functions and supply needs of the Government. Yet the Commission is aware that any legal action seeking relief as rigorous and comprehensive as the one under consideration, whether based upon the anti-trust laws or not, has a tendency to becloud relationships between the Government and industry. Such considerations, however, are speculative and difficult to appraise with certainty.

In considering the effect of the prayer for divestiture by the oil company defendants of their transportation and marketing functions, the Commission recognizes that, apart from other considerations, the existing organizational structure of the oil industry is well adapted to the defense program. It simplifies problems of supply, and facilitates the making of firm and long-range commitments. Divestiture may entail a loss of technical management and efficiency. The readjustments contemplated by the suit, and the process of habituation under a new set-up, will involve complications and delays. Curbs on capital expansion, certainly during the period when the split-ups are still in contemplation and not yet in effect, must be anticipated. Doubts and uncertainties may arise as to whether a company should undertake capital expansion in properties which may be divested, as to who will be able to afford such expansion (in view of the prospective division of capital resources), and even as to who could appropriately apply for Government assistance in such expansion. Eventually the Government will of course find some way to assure its supply. But time is precious.

The Commission finds it impossible to estimate with precision or exactitude the extent to which obstacles to industrial preparation for national defense are presented by the relief prayed for in the complaint. However, the Commission does not suggest that the proposed suit should be abandoned. The Commission feels it appropriate to point out, nevertheless, that to a greater or less degree certain prayers for relief may hinder the defense program. The Commission cannot undertake to meet the burden of proving, with court room evidence and logic, that such hindrances will ensue. But this balancing of national policies and weighing of judgments is peculiarly a matter for determination by executive officers rather than by judicial bodies accustomed to reliance upon legal precedents. And even where the likelihood of interference with the emergency effort cannot be explicitly demonstrated, substantial possibilities should control, especially when these are examined in the light of the rapidly expanding requirements for national defense. Some of the problems presented by the prayer for relief may here be elaborated.

In certain instances the proposal that the larger oil companies be required to divest themselves of all direct or indirect ownership or control of facilities used in marketing petroleum products may affect the construction of such facilities pursuant to negotiations now under way or in prospect for national defense purposes. The proposed divestiture would involve not only local bulk plants, storage facilities and service stations but also trunk marketing facilities such as gasoline pipe lines, barges, tank cars and terminals for petroleum products. At present both the Army and the Navy are interested in having private capital construct pipe lines to transport gasoline to the east coast states without the necessity of the long haul around Florida and up the Atlantic coast, which in time of emergency might be difficult and in any event would require a large convoy service. Moreover, in time of emergency it would be possible to take a part of the burden of the gasoline deliveries to the east coast through these gasoline pipe lines and in turn release tankers for the purpose of handling the essential products such as Navy fuel oil which cannot be handled in crude oil or gasoline pipe lines. These gasoline pipe lines would also afford

Illinois well drilled by Caterpillar Diesel to 3,000 ft. in 25 days an illustration of the speed and flexibility of the present industry set-up.

exceptionally desirable locations for some of the reserve stocks of aviation gasoline for both the Army and Navy since deliveries can be made at low cost and removal can be effected readily even in time of emergency. An initial expenditure of approximately $13,000,000 is involved in the gasoline pipe lines now under consideration and it would be desirable to have private capital construct similar equipment for emergency use in other parts of the country.

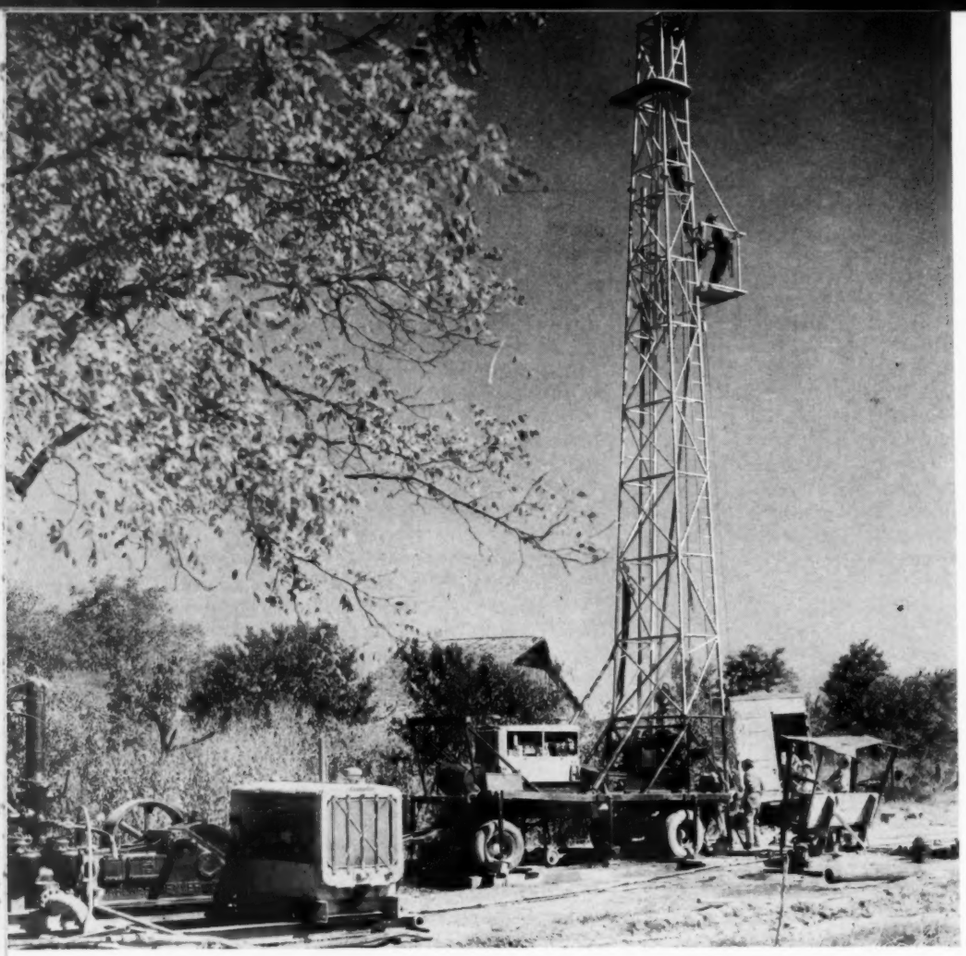
With respect to marketing terminals the program of the Army and Navy to care for the greatly increased stocks of aviation gasoline and Navy grade fuel oil has not yet been completely formulated. The Army plans to locate most of its interior reserve storage at points on gasoline pipe lines. Such location of large buried storage facilities would not only be virtually invulnerable but would make it possible to deliver the gasoline to the Army through any of the industry tap points or bulk plants located along the gasoline line or lines to which the Army storage would be connected. In addition, the Navy is giving consideration to the location of some of their reserve storage adjacent to or connected with petroleum products pipe lines at existing industry terminals. This would greatly reduce the investment in docks, lines, utilizing facilities and so forth and also minimize the labor required to guard and operate these facilities.

It is clear that substantial additions to the gasoline pipe line and terminal storage capacity of the industry will be necessary under this program. Arrangements and understandings to secure such gasoline pipe lines and storage may have to be discarded and delayed until the ability to perform is clarified, and later new negotiations begun with new parties if the existing companies are required to divest themselves of such facilities. Moreover, we must take note of the fact that the Government may well encounter hesitancies and delays on the part of refiners who are asked to extend their contractual commitments, particularly since substantial investments are necessary to meet anticipated demands and, indeed, are now being requested. Several of the larger oil companies may face financial difficulties due to the impact of the current international conflict on the returns from their foreign properties. And granting the relief prayed for in the draft complaint will of itself diminish the capital resources available for particular products. Even Government financing assistance would undoubtedly be delayed pending determination as to the proper identity of the borrower and terms of the loan.

Another proposal is that companies be prohibited from exchanging gasoline and other petroleum products. As a practical matter this would probably require the scrapping of the Army and Navy plan to insure the ready availability of Navy grade fuel oil and aviation gasoline at terminal storage points and would increase the cost of such products to the government. In any event this would increase the actual amount of transportation required, which would be highly undesirable in any period of emergency.

The draft complaint proposes that the larger oil companies be ordered to divest themselves of all direct ownership in the various media of transportation whereby crude oil is brought from the well to the refinery. These include primarily crude oil trunk pipe lines and tankers.

Pipe lines today are admittedly utilized as plant facilities of petroleum refineries and afford to refineries of integrated companies the steady supply of crude oil regarded by such companies as essential to low cost continuous operation. Divestiture of ownership in these facilities might under certain circumstances increase the difficulty of obtaining



Portable rigs capable of relatively deep and fast drilling comprise but one part of the industry characterized by the National Defense Advisory Commission as well suited to requirements of National Defense.

supplies. Such a potentiality would be particularly disadvantageous with respect to particular types of crude oil, used in the manufacture of high octane aviation gasoline and toluol specified by the Army and the Navy, a shortage of which is indicated by preliminary estimates of experts of the raw materials division of the Commission. Some expert opinion holds that the divestiture of crude oil pipe lines would lead to increase of cost to the government or even to the discontinuance in some instances of transportation of crude oil, where the transportation in and of itself is relatively unprofitable. It is similarly suggested that divestiture would delay or discourage construction of new connections. All the larger refineries and many of the smaller ones located on the Gulf Coast or in California have some crude oils available to them from their existing crude oil pipe line connections which would be useful for the production of these special materials. The curtailment or stoppage of the pipe line supply of these crude oils would occasion refiners difficulty in meeting their commitments under government contracts and consequently the prospect of pipe line divestiture might delay capital investment in necessary facilities to manufacture the refined products.

The prospective divestiture not only may complicate refiners' contractual commitments, but also may intensify the problem of financing certain additional crude oil pipe line construction. In order to safeguard against disruption of transportation in time of emergency, looping of trunk lines and the installation of additional pumping stations is contemplated. Studies to determine the necessary amount of such new construction are now in progress.

The commission wishes it to be understood that this general outline of problems to be met in the working out of the defense program does not mean that it in any way endorses the continuance of alleged abuses in crude oil pipe line operation. On the contrary, as has been indicated generally, if there are abuses, it favors their elimination, particularly if they result from any illegal combination or conspiracy. However, it does not feel qualified to discuss this phase of the proposed suit.

Capital problems are of course also presented by the proposal to divorce tanker facilities. A large proportion of the present tanker capacity of about 4,100,000 dead weight tons is approaching the end of the twenty-year period of useful life. The supply of crude oil to the refineries by tankers must be safeguarded. However, it would appear that there is no absolute shortage of tankers foreseeable at the present time since new tankers already under construction plus tankers now chartered in foreign service which could be put in domestic service would probably meet our needs. The direct needs of the Army and Navy probably would not require a large proportion of the tanker capacity.

In this general regard, you are advised that there is in the process of negotiation under the auspices of the Maritime Commission and the Navy Department an arrangement for allocating equitably as between the various companies the burden of supplying tankers to the Navy in time of emergency. If the suit is filed in the manner proposed, negotiations will have to cease. If effect is given to the proposal in the draft prayer, a new program will have to be devised and negotiated with the possibility of increased cost to the government.

The American Petroleum Institute

The Commission, in its technical study of defense requirements, does not have to rely on trade associations for information and contact with their respective industries. It is true of course, that the Institute provides information on petroleum statistics which are not now available elsewhere, and arrangements would have to be made to supply this need.

Conservation of Crude Petroleum Resources

Military authorities have estimated that during war the requirements for petroleum products would increase about 25 percent above normal peacetime needs. On the basis of the 1939 consumption of crude petroleum of 1,250,000,000 bbl. an emergency would lead to additional needs for somewhat more than 300,000,000 bbl. a year. These estimates were made before the adoption of recent plans for expansion of the air force and extended mechanization of the land forces and are constantly being revised upwards.

Our present reserves of crude petroleum have been variously estimated but probably approximate something in the neighborhood of 18,000,000,000 bbl. Consequently, there is no immediate problem of an over-all shortage of the basic raw crude though, as has been indicated, there may be problems with respect to certain crudes peculiarly valuable for military or naval use. The expansion, mechanization and rigorous training of the armed forces would certainly bring about a vast acceleration in the rate of production. If this is not accompanied by sound methods of conservation, a protracted emergency would seriously diminish the oil resources of the country. Sound conservation is of the utmost importance to any adequate defense program.

It must be remembered that the problem of crude reserves is not solely one of the amount of oil in the ground. The effect of increasing production per well would be a lower ultimate recovery. As time goes on, the lifting cost of the crude substantially increases and fewer barrels per day are recovered. Thus, though by simple arithmetic it would appear that the country's reserves are good for more than ten years under emergency conditions, declining production and higher prices for petroleum products will arrive long before exhaustion of reserves unless the discovery rate is maintained and production is effected with a minimum of waste. The possible adverse effects upon the Government and the consumer are clear.

In recent years, an expanding national demand for petroleum products has been met by the discovery of new sources of petroleum approximately equalling the amount of products consumed per year. It appears vital

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Solemn faced, the jury assembles at Madison to demonstrate on behalf of the administration the perils of oil industry operation without the guidance and protection of federal control.

that this rate of discovery remain unaffected. More and more, the business of prospecting for oil has come to depend on the availability of large capital resources.

In the first instance, it seems that reduction of the size of the existing units in the industry will leave less capital available for exploration. Secondly, although the intendment of the draft complaint, and particularly Paragraph (17) of the prayer for relief is not clear, the power of the companies named as defendants to develop additional reserves may be inhibited.

In addition, a development widely endorsed by federal and state conservation authorities has been the organization of a newly developed oilfield on a unit basis. The proposed suit would apparently prohibit such activities many of which are now carried out under the supervision of the Department of the Interior. These unit plans are deemed a major force in conservation since they reduce the number of wells to be drilled, conserve gas or hydrostatic pressure and otherwise conduce towards scientific production. This, of course, means lower investment costs per barrel of ultimate production and insures generally lower production costs and higher ultimate recovery of oil.

After due consideration which may or may not have included an administration offer to withhold prosecution of the suit in return for abatement of opposition to federal control, the Department of Justice filed a complaint in U. S. District Court against twenty-two major oil companies and the American Petroleum Institute on September 30th. The purpose of the present action is considerably modified in deference to the representations of the National Defense Advisory Commission. It no longer aims at the destruction of the present integrated form of important units of the industry, but prays for relief for independent operators and consumers; the former from conditions under which they allegedly can not operate profitably, and the latter from excessive product prices, artificially maintained by the defendants.

An outstanding feature of the action is set forth in the official statement of the Department of Justice under the heading "Anticipated Results of the Action". Here it is stated that " . . . if the Department succeeds in this action, independent producers should receive higher prices for their crude oil, and independent refiners should be able to compete with the major oil companies. With competition restored to the oil industry, gasoline, fuel oils, kerosene, and lubricants should be sold at lower prices to the consumer who should then receive the benefits of technological improvement, and the opportunity to purchase a variety of products."

The American Petroleum Institute comes in for heavy criticism in the statement of the Department of Justice. The complaint alleges that the defendants have conspired to restrict production of crude oil and manufacture of petroleum products. These restrictions it is alleged are accomplished in part through a system of reports made to the American Petroleum Institute, covering the amount and locations of all stocks of petroleum products, owned and held by each of the defendants. On the basis of these reports it is charged, the Institute is able to make suggestions as to the amounts of petroleum products which should be manufactured and maintained in storage. The complaint further states that these amounts are less than the quantity which would normally be produced and manufactured. It is alleged that the Institute's suggestions are adopted by the defendant, thereby accomplishing the restrictions which are complained of. The complaint further states that the defendants have agreed upon a price fixing program, covering the sale of petroleum products, marketing and price policies, methods and practices for fixing prices and stabilizing price structures, for lowering prices wherever they wish to eliminate independent competitors and raising prices wherever the competition of independent competitors has been eliminated. It is alleged in the complaint, that these agreements are reached at frequent meetings held under the auspices of the Institute.

The Department of Justice states that the emphasis of this action is not only in the interest of independents but in the interest of consumers who have not as yet benefited by the recent successful prosecutions in the Ethyl Gasoline case and the Madison Oil case.

In addition to the principal suit directed against twenty-two major oil companies and the American Petroleum Institute the Department of Justice contemplates three additional suits, one against the Philips Petroleum Company and the Philips Pipeline Company in the District Court of the United States for the district of Delaware. The second, against the Great Lakes Pipe Line Company in the same district and the third against the Standard Oil Company of Indiana in the northern district of Indiana. Each of these three actions are based on the charge that major oil companies receive indirect rebates from common-carrier pipelines on the oil which the major companies ship.

It appears therefore, that the Department of Justice will proceed with its action against the oil industry, although the scope of the action will be less sweeping than originally planned. The suit will proceed simultaneously with the enlistment of the resources of the industry in the building up of National Defense.

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Federal Oil Control Has Been Sustained Roosevelt Policy

Successive Legislative Proposals Alternating With Prosecutions by Department of Justice Convey Message That Industry Must Accept Domination by Washington or Face Attempted Disruption by Legal Assault.

ALTHOUGH the seven and a half years of the Roosevelt Administration have seen enactment of only two major laws directly affecting the petroleum industry a survey of the period presents a picture of continuous activity, most of it directed toward the extension of federal control over this industry.

For two years the industry operated under the controls of the National Industrial Recovery Act and since the intermediate period which followed N. I. R. A.'s termination by Supreme Ccurt decision, several measures have been proposed looking to the expansion of federal authority, although the only important enactment has been the Connally Hot Oil act regulating interstate commerce.

Meanwhile congressional committees, government departments and agencies have conducted investigations and surveys looking to further federal regulation, culminating in the presentation of the Cole bill, drafted in the Department of the Interior and still pending in the House Interstate Commerce Committee with action by the present Congress unlikely.

One recurring but subtle purpose is apparent throughout all the contradictions and cross-purposes that characterized the petroleum policy of the Roosevelt administration. The desire for federal control of the industry is the thread that binds together so much seemingly purposeless maneuvering and that alone justifies the expression "petroleum policy" as applied to the motives of the administration in regard to the United States' second largest industry.

Two lines of procedure have been followed. On the legislative front the effort has been to shift regulation from the states to the national government on the claim that this is the only effective way of establishing conservation and

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Two significant buildings in the New Deal's seven year campaign to bring the industry under federal control: Either the industry submits to being run by Ickes from the Department of the Interior on left, or it will continue to face trial in federal courts such as the Madison court house at right.

stability. At the same time, the Department of Justice has conducted a series of prosecutions against members of the industry on the alleged ground that they were following the same practices of conservation and stabilization that the federal authorities wanted Congressional permission to impose. While these methods may seem to be contradictory they form in effect a double barrelled weapon carrying the message to the oil industry that unless it accepts federal control, it will find the path of independent operation a rocky road to travel.

Following the anti-trust suit against 27 corporations and 37 individuals for operating a price stabilization program started under federal direction and continued with implied federal sanction, indictments were sought against companies and individuals in the Pacific Coast division of the industry. These suits were compromised by inducing the companies to submit *nolo contendere* pleas and to pay nominal fines. The third chapter in the drive to break up the existing organization of the industry was the projected action to force the "disintegration" of 22 large companies in the eastern states which was halted temporarily by the report of the Defense Commission showing that it might seriously hamper defense plans now under way.

Attorney General Jackson has since announced that the suit is to go forward but that it is to be confined to charges of price fixing, restraints on production and discrimination against smaller competitors. The attempt to dismember the companies by forcing them to relinquish their transportation and distributing facilities has been postponed because of the disastrous effect which it threatened to have on the nation's defense work.

In the tax field Congress on three occasions has continued the one-cent-a-gallon tax on gasoline imposed in the Revenue Act of 1932. In the Revenue Act of 1940, the so-called defense tax bill, this impost was increased 50 percent to 1½ cents per gallon.

Briefly the legislative and administrative activities of the Administration may be catalogued as follows: the National Industrial Recovery Act, the petroleum investigation of 1934, the Connally Act and the Oil Compacts, the Navy's efforts to obtain title to tidewater oil deposits, the oil investigation by the Temporary National Economic Committee, introduction of the Cole bill for federal regulation of the industry and the licensing for export of high-test aviation gasoline and lubricating oil in a manner amounting to an embargo except for Western Hemisphere shipments.

As the latest development the Reconstruction Finance Corporation has moved to set-up a new corporation to acquire large stocks of high-test aviation gasoline for the Army and Navy. It will be known as the Defense Supplies Corporation with a capital of $5,000,000. Fifty million dollars has been allocated by the R. F. C. for the purchase of this gasoline and storage at strategic points throughout the country will be selected.

Any history or evaluation of the legislative and administrative activities of the Roosevelt Administration relating to the petroleum industry must take into account the situation confronting the industry when the Administration took office March 4, 1933.

The period of 1930-1933 had been marked

by a series of new pool discoveries accentuated when the potential of the East Texas field became apparent in 1931. That year signalized the first proposal for an interstate oil compact presented to the then Federal Oil Conservation Board by the Oil States Advisory Committee composed of officials of the oil producing states, principally those of the Mid-Continent area.

As a result, Oklahoma, Kansas and Texas entered into an informal compact setting quotas for each state's production for the remainder of 1931 and the entire year 1932. Volunteer committees, acting at the request of the Federal Oil Conservation Board, published a series of estimates of domestic petroleum requirements for the guidance of the states and the industry. From mid-year 1931 the average posted price for average Mid-Continent crude rose from 18 cents a barrel to 92 cents in April 1932, but despite some postage as high as $1.04 a barrel in October 1932 the pressure of oil on the market forced the price downward until 1933 found crude again below 50 cents a barrel. Thus, while improvement had been achieved during the initial days of proration, increased potentials, more and more wells, and bootleg oil combined to bring the industry back where it started from. By January 1933 it was clear that attempts at curtailment had been unsuccessful and the industry faced a definite crisis.

An effort in the Senate early in January to bring about a price investigation by the Federal Trade Commission failed through lack of action on the part of the House and the developing situation caused Secretary of the Interior Ickes on March 27, 1933, to convene a conference of the governors of the oil producing states, the recommendations of which were submitted to President Roosevelt. On April 3, the President, in reply, announced he was prepared to accept the recommendations and to ask Congress for legislation "prohibiting the transportation in interstate commerce of any oil or the products thereof produced or manufactured in any state in violation of the laws thereof."

This was the first suggestion of legislation which became the Connally hot oil act in 1935 but not until after the period of NRA and the operation of the Code of Fair Competition for the petroleum industry, which with the hot oil act, and its subsequent extensions constitute the major federal measures for control of the industry in the last seven years.

During the week of the Governors' conference in Washington in 1933 the production of the East Texas field increased markedly and the national production for the week ending April 1 was 600,000 bbl. a day higher than the production recommended by the conference (2,000,000 bbl. daily). Shutdowns in important fields, including three in East Texas, emphasized the magnitude of illegally produced oil in the latter area, estimated at the time as approximately 150,000 bbl. daily.

At the same time when this situation was developing in the producing fields, Washington was witnessing an unpublicized but bitter struggle waged by Secretary Ickes to obtain control of the industry. A move was on foot to change the name of the Department of the Interior to the Department of Conservation. The United States Bureau of Mines in the Department of Commerce was shorn of several of its functions and attempts were made to assign these duties to the Interior Department. Such efforts, however, met with uncompromising opposition from the Commerce Department and while this interdepartmental war engaged the attention of the administration, the impact of the critical Texas situation was being felt in Congress. Taking advantage of favorable legislative conditions thus created, identical bills were introduced on behalf of Secretary Ickes by Senator Capper of Kansas and Representative Marland of Oklahoma the intent of which was to invest the Department of the Interior with power "to preserve and protect the correlative rights of the states, and regulate the transportation and sale in interstate and foreign commerce of natural gas, crude petroleum and the products thereof."

During the same period legislation which was later to be known as the National Industrial Recovery Act was being considered and the President on May 20 addressed letters to the Senate and House relative to incorporating in the recovery bill special provisions covering oil. Out of this grew Section 9 of NIRA, the first two paragraphs dealing with pipelines and the third, Section 9(c) with the prohibition against transportation in interstate and foreign commerce of oil produced or withdrawn from storage in violation of state law.

The order applying this authority was issued July 11 and its administration delegated to the Secretary of the Interior, who in turn issued general regulations prohibiting such movements of oil except upon affidavits certifying that the oil had been produced or withdrawn as prescribed by state law. The first order was of national application but by superseding order the area of application was restricted to the Oklahoma City and East Texas fields.

Since the Secretary of the Interior was administrator of both the Petroleum Code and Section 9(c) of NIRA it is fitting to mention the code activities, made effective September 2, 1933, before considering the transition from the "affidavit period" to the "Tender Board period" under Section 9(c).

The work of the Code Authority and its Planning and Coordination Committee was concentrated, at the outset at least, on production, although the code contained sections covering oil refining, marketing and wages and hours. The code provided means by which market demand could be allocated to the producing states. Article III of the code containing provisions relative to the production of crude oil dealt with (1) limitation of imports of crude petroleum and petroleum products for domestic consumption; (2) withdrawals of crude oil from storage; (3) estimates of required crude oil production to balance consumer demand and allocation among the states; (4) relationship between representative crude oil and gasoline prices; (5) establishment of price schedules and determination of cost of production; and (6) planned development of new pools.

During the code period, imports of petroleum and its products were held down. Withdrawals of oil from storage were controlled; allocations were followed within an average of 4.7 percent (excess), and production was held to a comparatively flat level, relatively free from wide seasonal fluctuations; studies were conducted on the cost of crude oil production, and more than 350 plans for the orderly development of new pools were approved.

Returning now to Section 9(c) the gradual increase in the amount of crude petroleum produced in excess of allowables in the summer of 1934, particularly in East Texas, made it apparent that the "affidavit" system was not effective. As it was only transitional in the development of legal principles and of the "tender" system later adopted and carried on into the Connally Act, detailed analysis is not necessary. Conflicting court decisions and difficulties of proving violations led to its abandonment and the establishment of the Federal Tender Board in October, 1934. Under regulations of the Board, certificates of clearance were required as a condition precedent to the movement of petroleum in interstate and foreign commerce out of East Texas.

The first Federal Tender Board ceased to function January 7, 1935 when the Supreme Court in the Panama and Amazon cases held Section 9(c) invalid as improper delegation of legislative authority. The court decision removing the power of the Secretary of the Interior to control oil shipments had scarcely been announced when Ickes, in pursuit of a fuller measure of federal control, declared that the opinion of the Court "emphasizes the necessity for specific and adequate legislation to effectuate a rational conservation program."

Then came the Connally bill in the Senate and its counterpart, the Disney bill in the House to be redrafted and passed in February 1935. While the debate in the Senate was based generally on legalistic grounds the discussion in the House guided by Administration-inspired forces turned on the necessity for federal and state cooperation in the enforcement of state conservation laws. This attitude was based on the exhaustive petroleum investigation conducted in 1934 by the Cole subcommittee of the House Interstate Commerce Committee, an investigation revived in 1939 at the request of President Roosevelt and resulting in the recent submission of a new draft known as the Cole Bill providing for federal control of the oil industry. This measure still is pending in the Cole subcommittee.

The annual report of the Secretary of the Interior for the fiscal year 1935 carries the story from the passage of the Connally Act to the end of June 1935 as follows:

> "On February 22, 1935, the Connally law was passed by Congress, eliminating the defects found by the Supreme Court in Section 9(c) by specifically prohibiting interstate or foreign commerce in hot oil.

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Attorney General Robert H. Jackson, left, leaves the White House to inaugurate oil industry prosecution as part of administration policy in which Ben Cohen, right, has an important voice.

Federal Tender Board No. 1 was established under this law on March 1, 1935, and shortly thereafter Federal Petroleum Agency No. 1 was set up under the same law to perform the administrative and investigative functions in connection with the applications for approved tenders filed with Federal Tender Board No. 1. The federal tender system has functioned effectively since that time and has prevented any substantial movement in interstate commerce of hot oil or gasoline out of East Texas."

With the Supreme Court's decision in the Schechter Case, May 27, 1935, the administration of the Petroleum Code was terminated. The Petroleum Administrative Board, which had assisted in the enforcement was reduced to a group that completed studies, either underway or requested by the President. On March 31, 1936 Secretary Ickes, as administrator of the Connally law, established the present Petroleum Conservation Division in the Department of the Interior.

This division continues to function as the Connally law which was to have expired by limitation June 16, 1937 was extended to June 30, 1939 and again extended to June 30, 1942. In addition to advising and assisting the Secretary of Interior in enforcement of this law the Division has duties authorized as follows:

"To discuss the work of any agency dealing with oil and gas; recommend action in any case brought to its attention; coordinate information; and, through appropriate channels, act as the contact agency with the Interstate Oil Compact Commission; present required data to Congress; attend oil and gas conferences in which the department is interested; cooperate with the oil-producing states in the study of physical waste and the enactment of uniform oil and gas conservation laws; and contact other departments of the government whose work deals in any measure with oil and gas."

While the administration was thus engaged in endeavoring to seize control of the oil industry, the industry itself turned its attention to clearing up conditions that might be used as an excuse for extending the scope of federal control. For this purpose the Interstate Oil Compact was executed in February 1935 and subsequently ratified by the states of New Mexico, Kansas, Oklahoma, Illinois, Colorado and Texas. Formal consent to the compact for an initial period of two years was given by Congress in Public Resolution No. 64, Seventy-Fourth Congress. This authorization was extended for another two years in 1937 and again in 1939 for a period of three years or until September 1, 1942.

The declared purpose of this agreement between the compacting states is "to conserve oil and gas by prevention of physical waste" and each state agreed that within a reasonable time it would enact laws to prevent wasteful drilling and spacing practices and to deny access to commerce for oil produced in violation of state conservation laws. Specifically Article IV of the compact denied any purpose "to authorize the states joining herein to limit the production of oil or gas for the purpose of stabilizing or fixing prices."

The Compact Commission by which the agreement is administered was organized with four permanent committees, conservation, coordination, consumption and imports and exports. Two additional committees: on economics and forecasting market demand were added in 1938. The committee on coordination at the organizing meeting was assigned the duty (1) to ascertain as accurately as possible the aggregate potential production of either oil or gas, or both, of each member state, and the percentage thereof actually being produced; (2) to report periodically as often as the Commission may direct, an estimate of the proven petroleum reserves, including the above ground storage, for the United States, together with a statement of the method and manner of preparing such estimates; and (3) to recommend plans whereby the producing ability of wells may be more correctly and uniformly determined among the member states and incorrect estimates of well potentials eliminated as far as possible.

The Commission recommended that the Department of the Interior, pursuant to the Connally Act, continue to collect and distribute to state enforcement agencies current information of tanker and barge line shipments and that the periodical findings of the Bureau of Mines with reference to consumption and supply and demand, be given proper and due consideration by state regulatory bodies. Efforts of the Commission were responsible for additional appropriations for the Bureau of Mines to add to information as to petroleum stock which had proved one of the most troublesome features of the Bureau's forecast work.

Although conditions in the industry were

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Senator Guy M. Gillette (seated) receives advice from Paul Hadlick at hearings on Gillette's administration-inspired bill to divorce marketing and transportation from producing and refining. Jackson has urged that the bill be pressed regardless of its detrimental effect on national defense.

not ideal, the Connally Act, together with the careful regulation of the more important oil producing states, removed the basis previously used to support the demand for full federal control of the petroleum business. The administration thereupon turned its attention to a less direct but significant approach to its objective.

Early in 1938 the Navy Department, presumably acting with administration approval, sponsored a resolution asserting federal title to all petroleum deposits along the seaboard of certain states. It was passed by the Senate only to die in the House with the termination of the Seventy-Fifth Congress despite the fact that it had been reported by the Judiciary Committee in rewritten form and restricted to the tidewater lands of California in which the Navy is primarily interested.

The resolution appeared again in the Seventy-Sixth Congress sponsored by Senator Nye of North Dakota and Representative Hobbs of Alabama in the Senate and House respectively. Exhaustive hearings in Senate Public Lands and House Judiciary Committees provoked general opposition from all interested states, particularly the oil-producing states of California, Texas and Louisiana. Others were represented in opposition because of the legal question involving federal and state rights to underwater areas within the three-mile limit.

Although immediate affirmative action on the proposal appears doubtful any legislation enacted is almost certain to be limited, for practical and test purposes, to the California area and to be based on national defense requirements. The Navy, in the San Joaquin Valley, maintains Naval Petroleum Reserves No. 1 and 2. According to Commander William G. Greenman, inspector of naval petroleum reserves, these now constitute less than 20,000 acres of what may be called good oil land.

Even this land, according to the Navy's contention, is threatened by drainage from private property checkerboarded within it and steady depletion by developments along the eastern border. In this connection Congress passed legislation authorizing the Secretary of the Navy to consolidate the reserve by removing private land through exchange or purchase, but it remains the view of the Navy Department that the reserve, as it stands, contains oil which can not be recovered with sufficient rapidity and in quantities ample for defense requirements.

The Navy has directed a survey to determine the extent of the reliance that could be placed on the future supply of crude oil of the state in relation to national defense and has been critical of the lack of machinery or organization in the state government of California for obtaining and disseminating information of this sort.

It may be assumed that the efforts of the Navy Department received administration backing because of their value in establishing precedents in regard to national defense reserves.

Unsuccessful in its attempts to secure a measure of control over the oil industry, comparable for example to the control it exercised over agriculture, the Administration embarked on a program to break down the resistance to government control that stemmed principally from within the oil industry itself.

If major and independent oil companies were unanimous in insisting on maintenance of free economy, it became important to the Administration to demonstrate how disadvantageous such freedom of operation, even with voluntary and state control could be. Hence another investigation of the petroleum industry, on which hearings were held after the introduction of the Cole bill but before the Cole committee started testimony, was initiated by the Temporary National Economic Committee. Although part and parcel of the T. N. E. C.'s program of presenting "a broad picture of the manner in which the American economic system functions" the T. N. E. C.'s presentation on oil elicited testimony from representatives of the industry on the same problems and covering the same ground subsequently worked over by the Cole committee.

In advance of its hearings the T. N. E. C. announced that the oil industry was "ideally suited" for such a presentation since it operates throughout the United States. Designating the show as a new type of congressional hearing the committee sought the cooperation of the American Petroleum Institute, other trade associations and independent groups in assembling the statements and the witnesses.

For several weeks the testimony ranged through discussions of profits and prices, alleged monopolistic control and on into the familar suggestion for divorcement of production from transportation and marketing. The last suggestion and its development both by T. N. E. C. and in hearings before the House Judiciary Committee on the Harrington bill directing such divorcement, may have afforded the basis for the suit since projected by the Department of Justice against a score of the major companies to bring about such divorcement on the grounds that pipelines and outlet ownership may be a violation of the Elkins Act directed against railroad rebating.

Dr. John Ise, economic adviser for T. N. E. C. told the committee that 20 major companies controlling only 23 percent of domestic producing oil wells, dominate virtually every other phase of the $14,000,000,000 industry. In some of its departments, he said, the oil industry does not "fit into the pattern of competitive business."

The view that the industry "is tainted with monopoly" was challenged for the industry by J. Howard Pew, president of the Sun Oil Company, who insisted that all elements of monopoly had been eliminated from the industry thirty years ago. Petroleum products, he pointed out, were the cheapest commodities in general use, despite the fact that the aggregate tax on the industry's activities and products is the highest in the land and the wages paid among the highest. As proof that the industry was carried on on a large-volume principle, Mr. Pew offered a table of prices of gasoline in twenty-six of the world's capitals, showing that on October 1, 1938 the 19.20 cents a gallon in the United States was the lowest with the 81 cent mark in Rome the highest.

No little testimony was advanced advocating revision of the anti-trust laws in manner which would permit voluntary agreements after the fashion of N. R. A., a line which opened up questions from committee counsel to show that there was little unanimity in government counsel on the current interpretation of the anti-trust statutes.

Under the program arranged by T.N.E.C. reports on the oil presentation are to be submitted to the committee by the Departments of Commerce and Justice upon which the committee in turn will make its final reports. Neither the departments' reports nor the committee's finding are expected for several months.

Another step in the campaign to break down oil-industry opposition to government control was taken late in 1937 when the petroleum industry was unexpectedly confronted with government prosecution of 27 corporations and 37 individuals in the Madison trials for violations of the Sherman anti-trust law which had previously been set aside in the NRA experiment for the specific purpose of encouraging agreements for stabilization of prices. Much has been written, pro and con about the trials which resulted in convictions in the Federal District Court of Wisconsin, their reversal by the Federal Circuit Court of Appeals and another reversal by the Supreme Court, in a 67-page decision by Justice Douglas with Chief Justice Hughes and Murphy not participating and Justices Roberts and McReynolds dissenting.

In 1934 when the retail markets were being swept with price wars the Petroleum Administrative Board cooperating with N.R.A. asked C. E. Arnott, vice president of Socony-Vacuum, as chairman of the marketing committee of the oil code authority's planning committee, to head up a voluntary cooperative movement to deal with the price wars. When he pointed out that in order to stabilize the retail market it would be necessary to stabilize the tank car market through elimination of "hot" oil and distress gasoline. Secretary Ickes as Administrator wrote Mr. Arnott as follows:

> "I am requesting and authorizing you, as chairman of the marketing committee to designate committees for each locality when and as price wars develop, with authority to confer, negotiate and hold hearings with a view to ascertaining the elements of conflict, and in a cooperative manner to stabilize the price level to conform to that normally prevailing in contiguous areas where marketing conditions are similar.

A general stabilization committee was appointed with headquarters in Washington and state and local committees set up. The Petroleum Administrative Board worked with the committee and its mechanical subcommittee until the termination of the petroleum code in the middle of 1935, the code authority defraying the expenses. The complaint of the government in the subsequent prosecutions was that this stabilization work, and more particularly the operations of what was called the Tank Car Stabilization committee was continued after the Supreme Court's final invalidation of NIRA.

Thurman Arnold, assistant attorney general, whose two years work on a suit designed to destroy the integrated form of the oil industry was completed just in time to endanger seriously the national defense program.

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"The alleged conspiracy," said Justice Douglas' opinion in which the judgment of the Circuit Court of Appeal was reversed and the contention of the government upheld, "is not to be found in any formal contract or agreement. It is to be pieced together from the testimony of many witnesses and the contents of more than 1,000 exhibits, extending through 3,900 pages of the record."

The Tank Car Stabilization Committee, according to the outline of the developments set forth in the Douglas decision, was the outgrowth of discussions at the Chicago meeting of the general stabilization committee. The tank car stablilization committee was "to consider ways and means of establishing and maintaining an active and strong tank car market on gasoline." The first meeting of the tank car committee was held February 5, 1935 and the second February 11, 1935. "At these meetings the alleged conspiracy was formed," said the Douglas decision, "the substance of which, so far as it pertained to the important Mid-Continent phase was as follows:

> "It was estimated that there would be between 600 and 700 tank cars of distress gasoline produced in the Mid-Continent oil field every month by about 17 independent refiners. These refiners, not having regular outlets for the gasoline, would be unable to dispose of it except at distress prices.
>
> "Accordingly, it was proposed and decided that certain major companies (including the corporate respondents) would purchase gasoline from these refiners. The Committee would assemble each month information as to the quantity and location of this distress gasoline. Each of the major companies was to select one (or more) of the independent refiners having distress gasoline as its 'dancing partner', and would assume responsibility for purchasing its distress supply. In this manner buying power would be coordinated, purchases would be effectively placed, and the results would be much superior to the previous haphazard purchasing.
>
> "There were to be no formal contractual commitments to purchase this gasoline, either between the major companies or between the majors and the independents. Rather it was an informal gentlemen's agreement or understanding whereby each undertook to perform his share of the joint undertaking. Purchases were to be made at the 'fair going market price'."

Shortly after the invalidation of NIRA, the tank car committee, the court decision pointed cut, held a meeting to discuss a future course of action and it was decided that the buying program should continue. "Accordingly," said the Douglas decision, "the committee continued to meet each month through February 1936, the procedure at these meetings being essentially the same as the earlier one and gradually the buying worked almost automatically."

(Continued on page 55)

Does Your Candidate Favor Reasonable GASOLINE TAXATION

Technological improvements such as the Lane-Wells gun perforator and the Hortonspheroid illustrated below have resulted in reduced costs for petroleum products: while gasoline prices decline, taxes increase with the result that consumers lose the benefits of such improvements.

Forthcoming Elections Give Motorists an Opportunity to Determine Attitude of Various Candidates on Gasoline Taxation Rates and Diversion of Gasoline Tax Funds to Other Than Highway Uses.

THE voice of America's automobile taxpayers, for years vainly crying in the wilderness of political indifference, has at last been heard. As a result, motorists' problems will receive greater attention at the elections on November 5 than ever before.

Typical of the current attitude toward motorists is the plank included in the platform of Maine's Republican party favoring "a lessening of the burden of taxation and regulations now borne by owners of motor vehicles."

The campaign platforms in several states specifically refer to restriction or reduction of gasoline tax rates. In South Dakota, the Democratic party promises not to advance that state's four-cent gasoline tax rate, and the Republican party in Iowa has similarly pledged itself to maintain the three-cent rate. The G. O. P. in Indiana and South Dakota have gone a step further and offer to slash current gasoline tax rates. The gas tax cut in Indiana was the only outright tax reduction advocated.

The most popular issue championed by candidates of both political parties refers to the safeguarding of gasoline tax and motor vehicle registration revenues for highway purposes. Tennessee and North Carolina are typical examples of the vote appeal which the so-called diversion issue can have.

Over the past five years Tennessee highways have lost $10,700,000 as a result of raids on the highway funds. Motorists have in-

sisted that this diversion be stopped and that a legal barrier be erected to protect the state's road funds. As a result more than 100 candidates for the legislature have been publicly advocating various methods of protecting highway funds.

In North Carolina, a traditionally Democratic state, every one of the six Democratic candidates in the primaries pledged himself if elected, to dedicate gasoline tax and license fee revenues to highways exclusively. The winning candidate proved to be J. M. Broughton of Raleigh, who declared, "Not one dollar of the highway money should be diverted for any other purpose. All of our highway funds are needed for road building and improvement. It would be folly to permit so magnificent an asset as our highway system to get into disrepair or fail to keep abreast of the rapid progress we are making."

That the diversion of road funds is a poor business policy is stressed in both the Republican state platform in Indiana and by the Democratic governor of Maryland, Herbert R. O'Connor. "We have put a stop, for all time, we hope, to the diversion of gasoline tax receipts to other than road purposes," said Governor O'Connor recently. "Even in the throes of the financial emergency in which the state was plunged, such diversion was a drastic error, an error from whose consequences it will take our state some years to recover, no matter how strenuously we try."

When voters in South Dakota, Idaho, and Nevada go to the polls on election day they will be handed a ballot giving them the opportunity to ratify or reject amendments to their respective constitutions. If adopted, these amendments will establish as a basic principle that money collected from motor vehicle owners in special highway taxes must be used for highways only.

Preliminary reports from these states indicate that all of the proposed amendments have more than a fighting chance of passage. Each has been approved by the state legislature. In addition, ratification of the Idaho amendment has been recommended by both major political parties, while the Nevada amendment has the blessing of the administration as well as some political leaders of the minority party.

The possibility of passage of the South Dakota amendment has been enhanced by two recent events. One was the insertion of a plank in the state Republican platform condemning the practice of diversion. Most potent influence, however, was the overwhelmingly favorable vote given a similar amendment last June in the neighboring state of North Dakota. The South Dakota amendment has the backing of many of the leading business organizations and all of the farm organizations in the state.

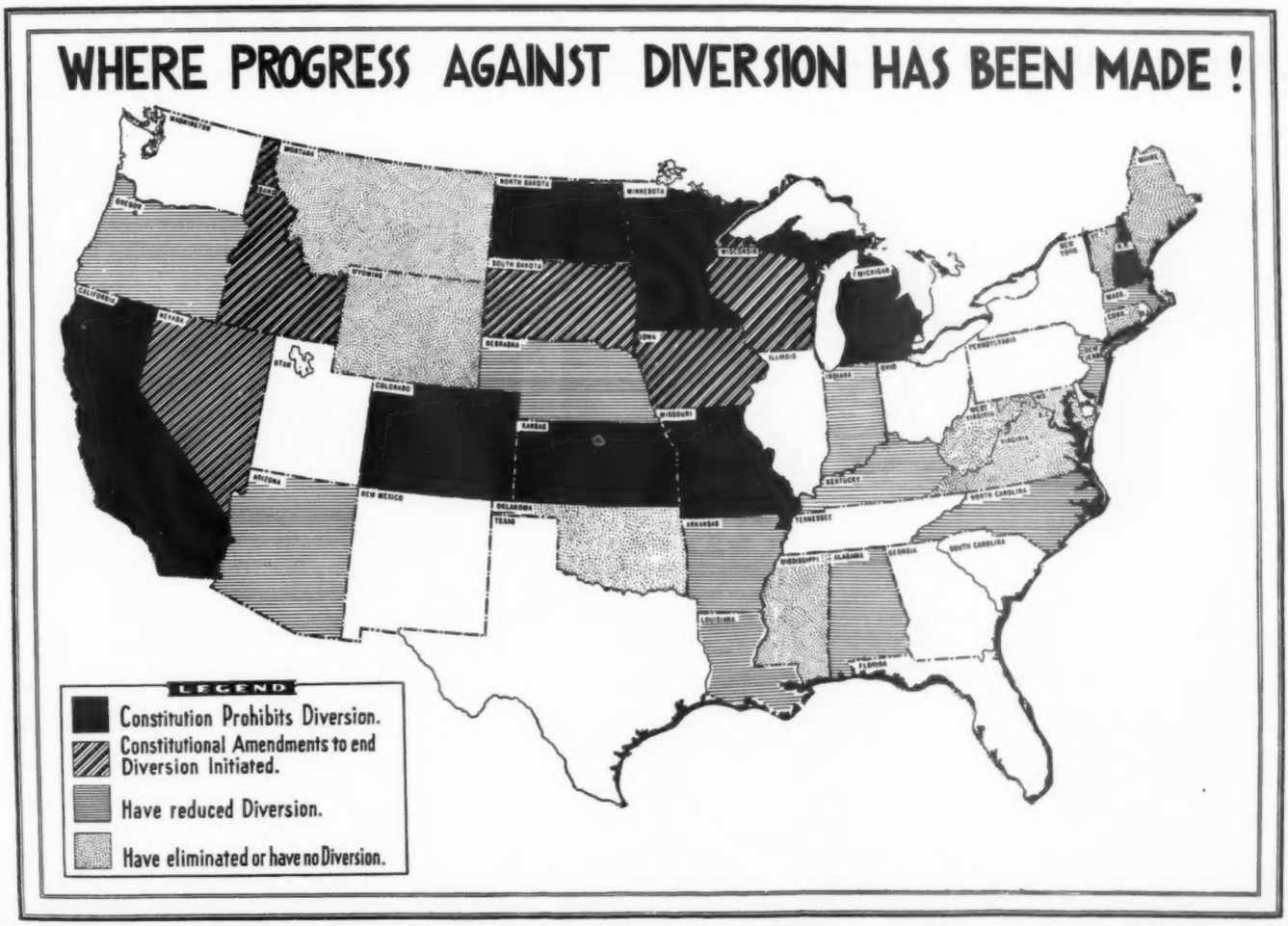
Considering the time required to adopt amendments, usually from two to five years, the rapid progress of the movement to safeguard highway funds has been little short of phenomenal in the past five years. The automobile had not been invented when most state constitutions were adopted, so no provision was made to ear-mark special highway tax funds for roads.

Minnesota was the first state to establish the principle that highway tax funds should remain inviolate, and Kansas and Missouri soon followed suit, but up to 1935 those were the only states in the Union with such provisions.

Similar amendments have since been ratified by the people of Colorado in 1935, by the voters of New Hampshire, Michigan, and California in 1938, and by the citizens of North Dakota in June of this year. With diversion amendments to be voted on in three more states in November and with amendments pending in Iowa and Wisconsin, the motorists of more and more states are being given a square deal on their special taxes.

Some states, of course, are solving the same problem in other ways. Ten states today have no diversion whatever, even though they have erected no legal barriers against the practice, and eleven other states are gradually cutting down the amounts diverted against the day when they can find it economically feasible to abolish the practice altogether.

The economic significance of eventual abolition of all diversion is indicated in data published by the U. S. Public Roads Administration which reveal that the nation's greatest present day highway deficiency exists in the heavily traveled route between Boston and Washington. This route crosses four states guilty of some of the biggest raids on highway funds; Massachusetts, New York, New Jersey and Pennsylvania. Total annual diversions in these states amount to $72,000,000 or enough to build a highway between Pittsburgh and Harrisburg as good as, or better than, the widely-publicized Pennsylvania turnpike.

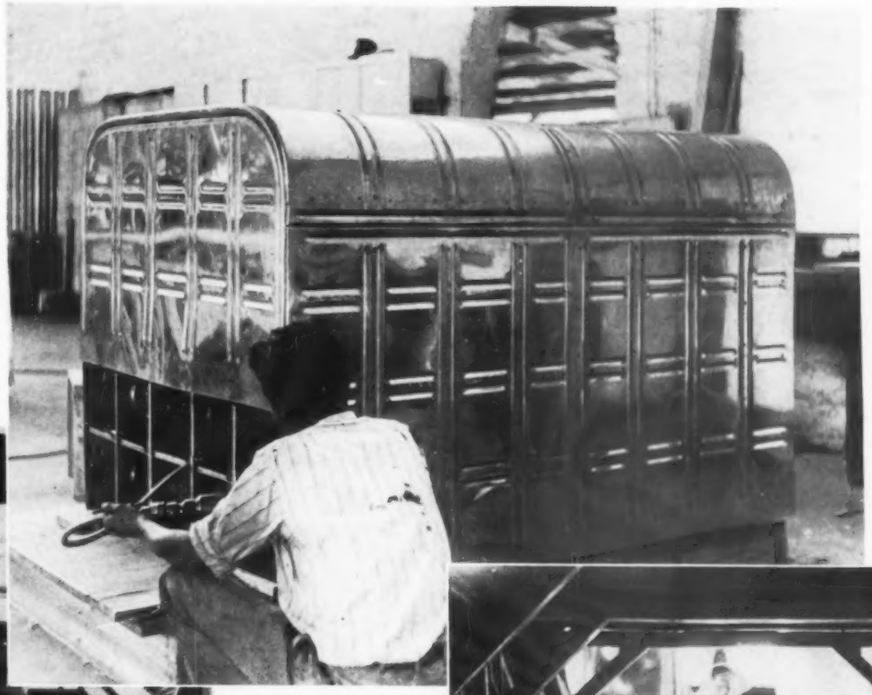

WHERE PROGRESS AGAINST DIVERSION HAS BEEN MADE !
LEGEND
Constitution Prohibits Diversion.
Constitutional Amendments to end Diversion Initiated.
Have reduced Diversion.
Have eliminated or have no Diversion.

NICARAGUAN Air Tanker Might Have Military Application

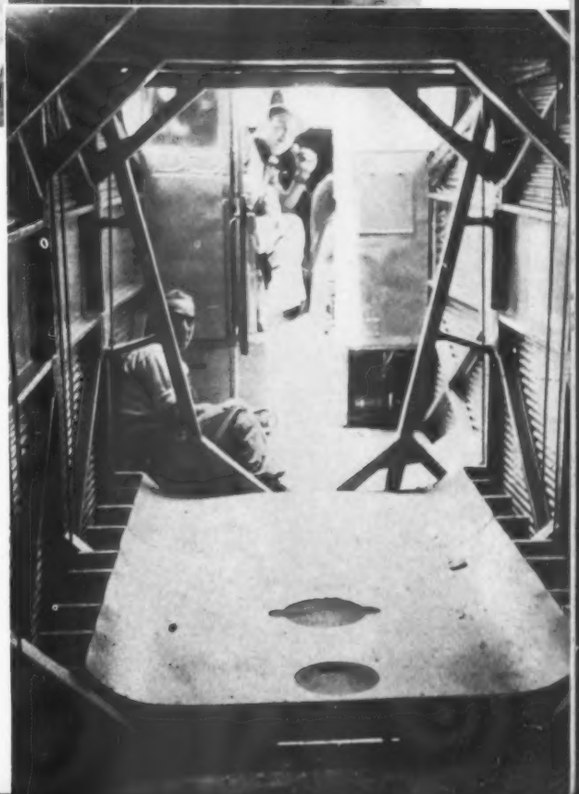
Present day operations of mechanized armies and air forces with their requirements for speedy and flexible fuel transport has concentrated attention on the possibility of developing air tankers. Reports have been received in fact, that such modern tankers were operating with the German forces and their application to British operations in the African desert is obvious. Meanwhile, in Nicaragua such an air tanker has already been developed and is in daily commercial use by Transportes Aereos Centro Americanos (TACA) as illustrated on these pages.

Constructed recently in TACA's factory at Toncontin, Honduras, this petroleum transport carries 600 gal. of fuel oil in a specially designed aluminum tank. While air transport of petroleum is not a new development, there is a considerable difference in pay load between transport of oil in customary drums and in a tank plane especially designed for the purpose. In addition to a definite saving in handling time, the all-payload of the tanker plane equals nearly three loads of the same number of gallons in drums. This tank plane makes four trips daily carrying a total of 2,400 gal. of oil needed for the Diesel and other power equipment being operated in Nicaragua's gold mining operations in the interior.

At the top of the opposite page is shown the airport at Alamicamba, Nicaragua, through which 10,000,000 lbs. of freight including substantial shipments of Diesel fuel will pass this year to be flown to the La Luz mines at Siuna. Just below, the flying tanker is unloading by gravity, an operation which takes six minutes and does not require motors to be shut off or pilot to leave the ship. The 600 gal. tank does not leave room for the pilot to enter by the side door; hence the ladder and hatch shown in the bottom picture. Just above is an air view of the river and airport by which freight reaches Alamicamba for transhipment by plane to the mines. At right and below may be seen the tank, cross-bracing, and floor plate by which this tri-



motor, TACA freight plane was converted to an aerial tanker. One of the two holes in floor plate permits emergency jettisoning of cargo; the other serves for normal gravity unloading.



OIL INDUSTRY'S LARGEST
8,600 H.P. of

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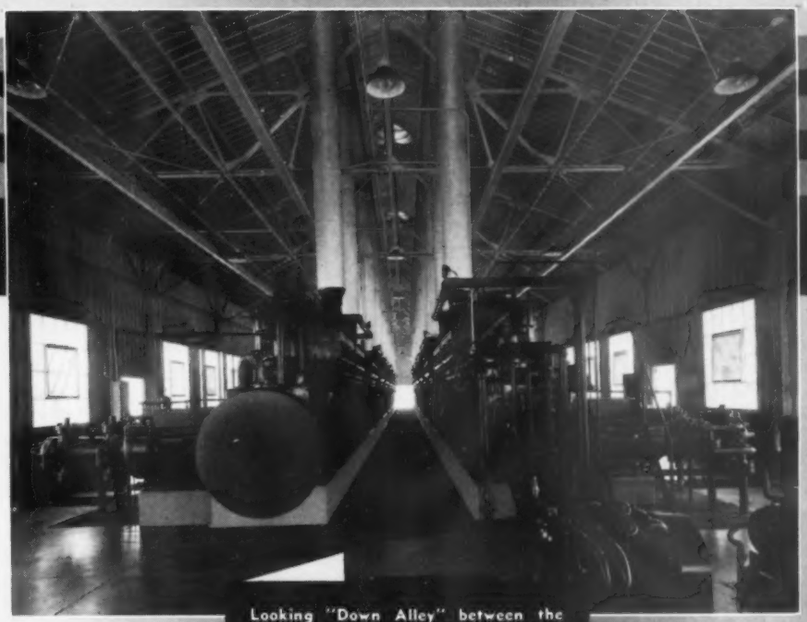
THE Continental Oil Company, at Ville Platte, Louisiana, has entered upon the largest and most ambitious pressure maintenance project on record. This project is proceeding upon the plan of drilling **the minimum necessary number of wells** to produce the area,—yet, through a most advanced and efficient application of large-scale pressure maintenance, driving the oil to these wells and **securing more complete recovery.**

The industry's largest compressor plant—here pictured—has been constructed at Ville Platte and is the heart of this great project. It is significant that CLARK "Angles" were selected as the compressor equipment. The installation utilizes CLARK "Angle" units ranging from 300 to 1,000 H.P., the huge battery totalling 8,600 H.P. The plant takes

COMPRESSOR PLANT
CLARK "ANGLES"

This photograph shows just half of the world's largest battery of compressors

Main Compressor Building, housing the 8,600 H.P. battery of CLARK "Angle" Compressors



Looking "Down Alley" between the two long rows of CLARK "Angles" set back to back

gas from the separators at 350 to 500 lbs. pressure, removes the gasoline by high-pressure absorption, and returns the residue gas to the formation at 3,000 to 4,000 lbs. pressure. It also takes low-pressure gas, boosts it up to absorber pressure, and handles it with the high-pressure separator gas. With this plant in full operation, the Ville Platte field becomes the most completely operated oil field in existence.

This plant includes the first installation made of the new CLARK 1,000 H.P. "Angle". This unit is our standard 8-cylinder "Angle" fitted with newly designed super-charged power cylinders with specially designed high-velocity-cooling water jackets, which give it 25% more power without increasing weight or shipping cost.

True Conservation Best Served by PRESSURE MAINTENANCE

By Dr. O. W. Willcox

While a Continuous but Frequently Submerged Battle is Waged in Washington for Conservation Through Federal Control, The Oil Industry Has Applied Itself Voluntarily to Perfecting Development Practice That Assures True Conservation Based on Engineering Principles.

(First of several articles on this subject: the second, which will appear in an early issue deals with a specific pressure maintenance project.— Edit.)

THE history of an oil well, or an oil pool, is divided into three parts. The first part is the period of search wherein the geologist, or the geophysicist, or the hopeful wildcatters are using such arts as they have in the effort to discover the hidden oil.

The second part begins when the drill has at last reached the pool; from then on the oil producer has nothing to do but allow the oil to flow to the surface under its own power, or to pump it from the bottom of the well if it lacks the internal energy to come up of itself.

The third part begins when the oil no longer possesses enough internal energy even to come to the bottom of the well bore where the pump can lay hold on it.

Then the oil producer has two options. He can decide to call it a finished job, pull out his pump, comply with the legal provisions governing the abandonment of oil wells, and look around for new oil pools to exploit; or he can decide to make use of one or another means for confering new energy on the residue of oil that now lies motionless in the porous underground formation.

The operator's decision on these options is a matter which affects not only his own interest but also the interest of the general public. There is much reason for believing that the supply of natural petroleum hydrocarbons will eventually be exhausted, and that the time is coming when the last oil pool will have been discovered. That time may be either near or remote, but when it does come the public will have to depend on other sources of petroleum products, which are then sure to be more expensive. Whether consciously or not, the public has a distinct interest in making the existing non-renewable supply go as far as possible. True conservation, as a public duty, requires that no oil pool which seems to be dead should be abandoned without a careful consideration of whether it might be brought back to life.

And if a dead or dying oil pool can be revivified with profit to its owners, so much the better all around.

The art of confering new energy on apparently extinct or moribund oil pools is called secondary recovery. It is a relatively new art, considering that the petroleum industry is now more than 80 years old and that the first crude attempts at secondary recovery were not made until about 25 years ago. Even so, the new idea still had to wait a long time before any considerable number of oil operators became interested in it.

If all members of the oil industry were alive to the importance and the necessity of availing themselves of known methods of secondary recovery, both in their own and the public interest, available petroleum resources would be immeasurably extended. Although most qualified petroleum engineers are informed on the subject it is still evident that some operators—the persons who have the final say—are more or less in the dark as regards the matter, especially those operations which tend to conserve the original energies of oil pools and thus to postpone or even to avoid resort to the more expensive forms of secondary recovery.

The circumstances which make it necessary and possible to employ artificial means of revivifying dead or feeble oil pools are more or less generally understood and may be summarized as follows:

In its virgin condition an oil pool is a porous underground stratum which is more or less completely saturated with fluid oil. This oil is sometimes above a lower stratum of water in the same porous formation, and this water may be under a hydraulic pressure amounting to thousands of pounds to the square inch. When the oil stratum is penetrated by the drill the pressure of the underlying water forces the oil out of the well to the surface (water drive) and when the last of the oil has been forced out, that oil well is definitely finished.

Or the oil in the porous formation may be under the pressure of an overlying gas cap which forces the oil to the bottom of the well bore and so to the surface (gas drive). Under that condition the oil will flow to the surface as long as there is sufficient gas pressure. When the gas pressure is exhausted and the well stops flowing the oil may still seep to the bottom of the well, from whence it may be pumped. Eventually the oil no longer seeps, and the oil pool becomes dead, or better said, is in a state of suspended animation.

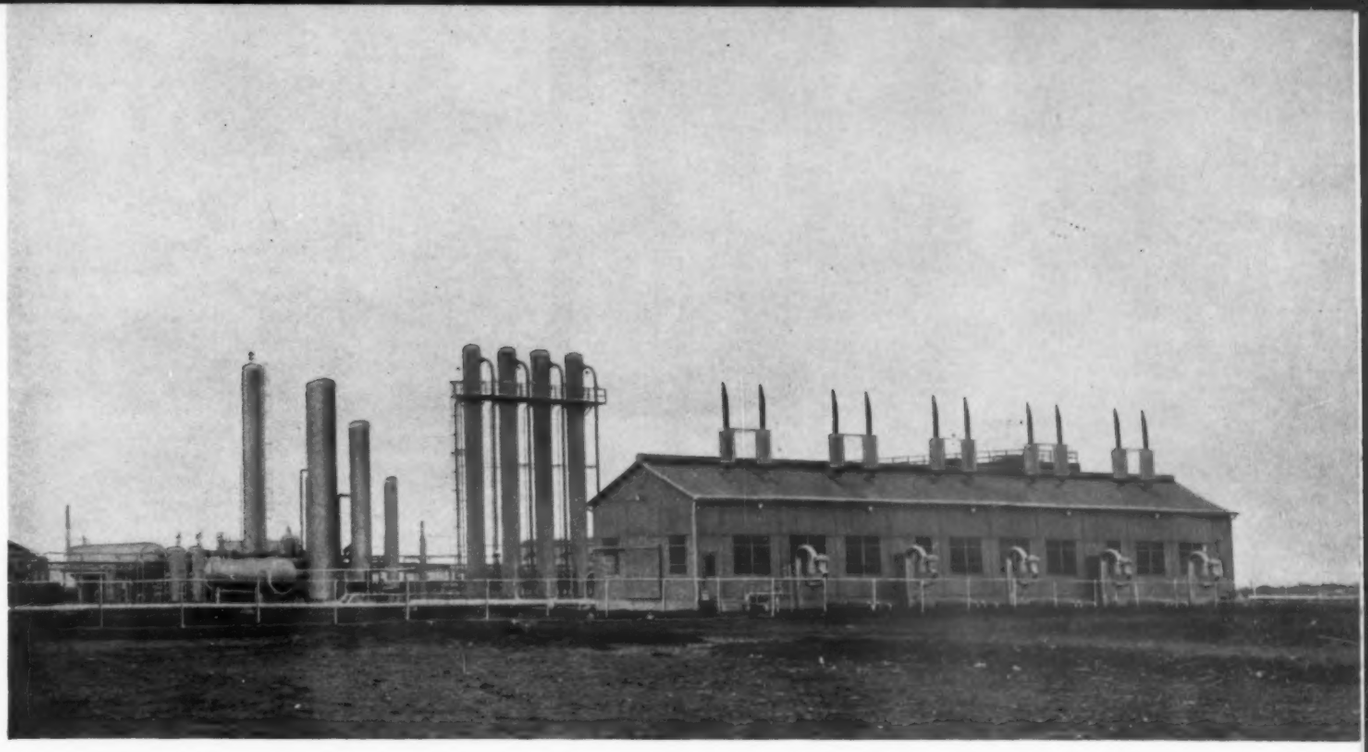
The possibility of restoring animation to the oil in an apparently dead oil sand lies in the following circumstances:

Oil, like water, will wet the surfaces of the grains of sand with which it is in contact and may fill the spaces between them. If the spaces between the sand grains are large a certain amount of oil will flow out of the sand by gravity if a path is offered to it, but a certain amount will remain. If the sand-pores are small they may be completely filled by oil which is nevertheless prevented by capillary attraction from flowing at all under merely gravitational forces. If a mobile fluid like air, gas or pure water is now forced under pressure into a well that penetrates one part of the inactive oil sand (input well) this pressure will overcome the gravitational or capillary forces that hold the oil motionless in the sand and will force it to move toward a well in another part of the sand (output well).

Such is the principle of secondary recovery as applied in the petroleum industry: the introduction of a mobile fluid under pressure into an inactive oil-sand for the purpose of sweeping out a residue of oil that will not flow of itself.

As we said, this seemingly elementary idea of assisting nature to yield up her store of oil was somewhat delayed in making its appearance in petroleum technology and it was accidental at that. According to recorded tradition, an oil property in Pennsylvania was overflown by a freshet and water penetrated to the oil-sand, whereupon it was observed that some previously exhausted wells in the vicinity were now producing oil. It was shrewdly suspected that the revivification of these old wells was a result of the pressure exerted by the invading water. Later on a similar invasion of a supposedly exhausted sand by water leaking from an upper formation by way of a faulty casing is said to have had a similar desirable result. An accumulation of such observations finally led to the conception of an artificial water drive as a general method of secondary recovery.

The artificial water drive has been applied with distinguished success in the Bradford, Pa. district, and from there has spread to



General view of a successful recycling operation in Banquete, Texas.

various other fields, as in Oklahoma. However, the artificial water drive has not been as widely adopted as the gas drive, because it apparently does not have the flexibility and convenience of the artificial gas drive. This article is therefore confined mostly to gas drive.

The concept of the artificial gas drive also arose out of what appears to have been an accidental circumstance. It is said that an oil operator in Ohio, for some undisclosed reason, connected a well that was uselessly blowing gas to an old well that was producing no oil. Then after several months and for some reason also undisclosed, he disconnected the old well and found that it was flowing oil. Acting on the hint, an outfit was set up near Marietta, Ohio, for blowing air under 40 lbs. pressure into an old oil sand that was about exhausted; the increased yield was gratifying. The undertaking was repeated in other places, and by 1926 a considerable number of operators were experimenting with what has become known as the "Marietta process" and air or gas compressors began to appear in the equipment of many non-flowing fields.

However, it was found that the Marietta process did not work in all cases, and at first there were more failures than successes. The next dozen years was a hard period of learning the reasons for the failures and how to avoid them.

It was in this period that the petroleum engineers rendered what is without doubt one of the most important of their many services to the industry and to the public. By finding solutions to the repressuring problem they have, in effect, made it possible greatly to increase the available supply of crude petroleum, and by that much to postpone the day when there will be an insufficient supply of this essential material. Out of the tribulations of these dozen years there has been developed a set of engineering principles and practices through which it is possible to make a success of repressuring in any oil field where the conditions in the oil reservoir are favorable. Of course, if the reservoir conditions are not favorable, there will be no occasion for repressuring. But the point is that it is now possible to recognize those conditions that will make repressuring a success, and conversely to recognize the conditions that will make it a failure.

In the present state of the art, repressuring (meaning artificial gas drive) is resorted to for accomplishing three fairly distinct purposes.

The first, or original purpose was to apply secondary recovery to depleted oil sands, of which there then was, and still is, a large number throughout the country. Such cases constitute the majority of existing repressuring projects and it is probably true that repressuring has not yet been applied to half the number of dead or moribund oil pools on which it might succeed.

A later development was the use of repressuring or recycling as it is called in this case, for the purpose of maintaining the original gas pressure of the pool. This development is a logical outgrowth of the recognition of decline of bottom-hole pressure as a cause of decline in the rate of production from oil fields.

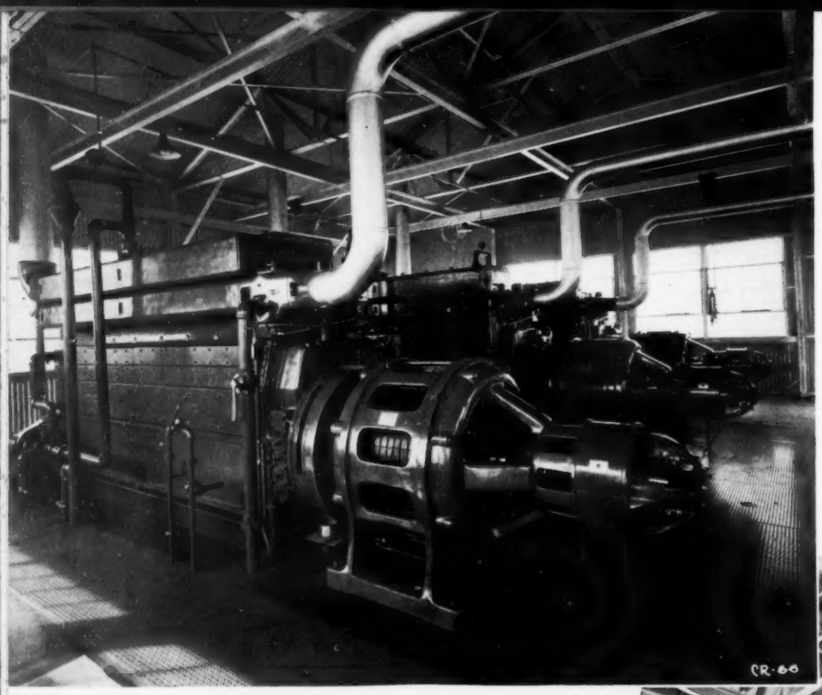
The third and most spectacular application of repressuring or recycling is in connection with certain petroleum reservoirs where special physical conditions exist that keep the oil in the form of vapor, or gas, which cannot be recovered unless the original gas pressure is maintained.

Leaving the third application for separate consideration the first application may be regarded as an effort to recover part of what has been lost on account of prior ignorance of the nature of oil reservoirs. The typical case is that of an average pool that has passed through the normal cycle of flush production with many flowing wells or even gushers. During this period the wells produced enormous quantities of gas under high pressures; this gas was stripped of the natural gasoline contained in it and the dry gas, for which there might be no available market, was thoughtlessly popped into the atmosphere. Then when the gas pressure that brought the oil to the surface was exhausted the wells went on the pump for as long as oil would seep to the bottom of the well bore in profitable quantities; after that the well or the lease was abandoned as not worth further attention. The oil statisticians, of course, dropped it from their inventory of the country's oil reserves. And yet that pool may have contained nearly as much recoverable oil as the operators had taken out.

There are doubtless hundreds of such abandoned oil properties that might be revived by repressuring. The time that has passed since abandonment does not seem to enter into the question. An apt example of this is a repressuring project that was recently inaugurated in East Titusville, Pa., a few hundred yards from the historic Drake well where the petroleum industry took its origin. Here, in the oldest oilfield in America and in a section thickly sown with old, abandoned and long forgotten oil wells the third Venango sand was found to have retained a gratifying percentage of saturation, and now supports a modern repressuring plant.

As we said, the experience of the past dozen years has made it possible to reach a safe conclusion as to whether or not an exhausted oil sand will profitably respond to a program of repressuring. The answer will be found by a systematic study of the facts in each case.

The first requisite is to find out whether the sand still contains a worthwhile quantity of recoverable oil. This will be shown by a coring survey. Cores are taken from one or more lines of wells across the property that will represent the sand as a whole. These cores are tested for their saturation, or the amount of oil figured as a percentage of the porosity, by which is meant the volume of the intergranular spaces. The thickness of the oil



Left, motors in the Banquete plant of the Coastal Recycling Corp. Below, Clark Brothers angle compressors rated at 8,600 h. p. in Continental's Villa Platte recycling plant. Opposite, main engine room and Clark compressors in a Texas repressuring operation.

bearing sand being known, the number of barrels of oil per acre-foot of the lease is readily figured. The next important fact to be ascertained is the permeability of the sand, which measures the resistance which the sand will offer to the passage of the repressuring fluid.

This has a direct bearing on the probable size and consequently the cost of installing and operating the necessary compressor plant. The coring survey will disclose other essential matters. It will show whether the sand is physically uniform or variable; the location of permeable and impermeable sections; the existence of tight zones that will require a higher pressure, and loose zones that need only a moderate pressure; where packers must be set to prevent the repressuring fluid from by-passing the relatively tighter zones vertically or horizontally, or to exclude water. Another important test on a core is to place it in an apparatus where compressed air can be forced through it and where the amount of oil displaced by the air can be measured.

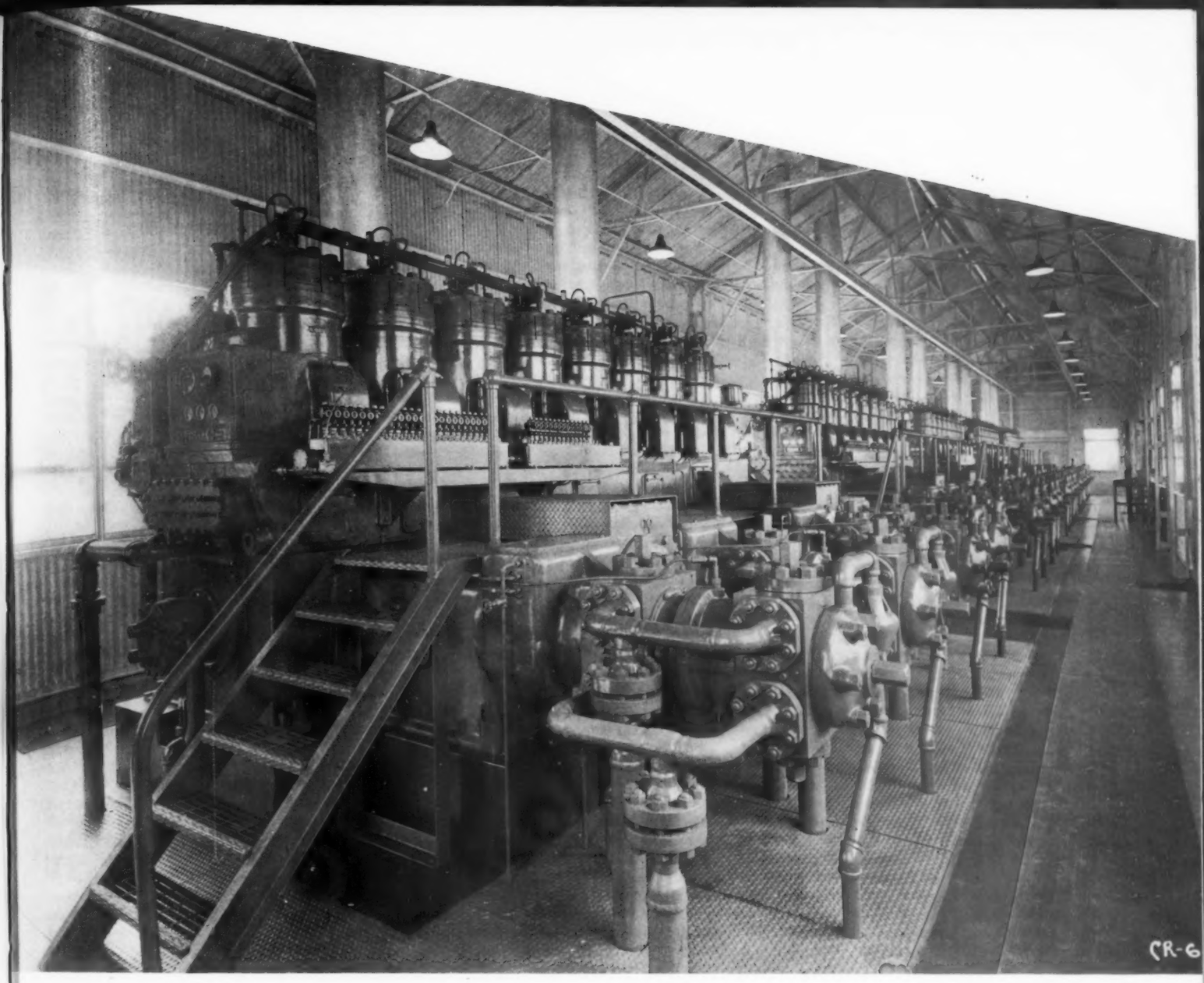
Then, when all the preliminary investigations and laboratory examinations have forecast the probable success of the project, the careful operator generally proceeds to make haste slowly. The preliminary observations are verified by an experimental field test on a scale that will not cost too much, and yet afford a definite basis for investment and operations. A certain input well is selected, carefully cleaned, and cored to disclose where packers should be set. The input well is surrounded by a ring of output wells in a five-spot, six-spot, or seven-spot pattern at distances indicated by the permeability tests. The output wells may be old wells if they are in good condition and are suitably spaced. Then a relatively small portable compressor plant is brought on the field and connected with the input well; pressure is applied by compressed dry natural gas (if available; if not, air will do), and maintained for several weeks. If there has been no mistake in the preliminary survey the output wells will begin to show satisfactory production. If the same process is applied on one or more other rings of output wells, a sure basis will be had for investing in a compressor plant for repressuring the whole lease. In this way guesswork is eliminated and failure avoided, or at least minimized.

While a careful preliminary study is necessary for getting a successful repressuring project started an equally careful control of operations is necessary to keep it on the road of success. Accurate measurement of daily operations is the basis of all well-managed industrial enterprises, including repressuring enterprises. The amount of gas going into the input wells should be known at all times, and corresponding measurements will be made of gas and liquid (oil, or oil plus water) issuing from the output wells. Such measurements will show whether everything is as it should be, or whether and where the pressure-gas is by-passing, and what should be done about it. Various minor operating maneuvers and tricks of the trade on occasion contribute much; these details are matters for an experienced petroleum engineer, or they may be studied out in the literature of the subject.

The economic limits to repressuring depleted oil sands will naturally vary with the conditions in each case, but cases are on record (in California) where repressuring has been profitable on leases as small as a quarter-section (160 acres), and on leases where the daily production per well had fallen as low as three or five barrels. The large southeastern Ohio-West Virginia region is perhaps typical. Here numerous 20 to 30 year-old pools were repressured; some of the projects succeeded, other failed, and the failures have been responsibly ascribed to omission to make a careful preliminary survey. In the successful ones repressuring has increased production two to nine times over the rate of production before repressuring; the average increase for this whole region has been computed at three to four times.

Among the factors that contribute to the success of repressuring projects we should not omit to include cooperation. Where an oil pool is under diverse ownership it may be difficult for a small lease-holder to repressure his property without driving some of his oil into the wells of receptive but unreciprocating neighbors; it can be done, but at extra expense. It is far better all around to get together and treat the whole pool as a unit; quite a number of successful cooperative projects have proved it. In many cases cooperation is balked by a stubborn minority who, it seems, can be moved only in their own and the public interest by legislation such as has recently been proposed in Mississippi, under which the regulatory body would be empowered to enforce unit operation on an equitable basis.

In the past, most existing depleted oil sands have arrived at that condition through a



process of what we now know to have been a course of deplorable waste. Not knowing any more about the real natures of oil pools than they then did, or perhaps being in a great hurry to pay out their investments in the shortest time and with the least amount of intellectual or physical effort, most operators took little account of what the wells were doing so long as they were delivering oil in profitable quantities. The natural gas that accompanies nearly all crude petroleum was in most cases stripped of its content of natural gasoline and the dry gas, if not marketable for domestic or industrial consumption, was regarded as a nuisance and popped into the atmosphere and thus was usually lost. It took a long time for many operators to realize that in throwing away their surplus gas they were discarding a valuable helper as well as an irreplaceable national resource, and it cannot be said that this truth has been taken sufficiently to heart by some producers who note with resignation that their production curves are declining, and that salt edge water is encroaching.

But it is now known or at least suspected by well informed petroleum engineers that an oil producer who wastes surplus natural gas, even where there is no immediate market or use for it, is in many cases doing himself and the public an injury. In the first place he is injuring himself because, if his property is under a natural gas drive, dissipating the gas means a loss of pressure, and that means a decrease in the driving force that is pushing the oil into the bore hole. The direct result is that the decline in the rate of production parallels the decline in bottom hole pressure. With the passage of time less and less oil flows out even while the well is in the gusher stage; the daily yield keeps on declining to the end of the pumping stage, and then the operator begins to think about clearing his decks for a repressuring project.

It is only recently that petroleum engineers have begun to ask: Why re-pressure? Repressuring means restoring a pressure that has been dissipated, and is something akin to locking the stable door after the horse has been stolen. Why not keep the pressure we now have instead of laboriously and expensively putting it back on the wells that will be yielding only a few barrels of oil a day, perhaps with much water? The idea now is (circumstances permitting) to save the existing bottom hole pressure from the day the well is brought in by using a compressor for returning the surplus gas back to the oil sand whence it came, there to maintain the original energy with which the pool was endowed. Under such a regime the mixture of gas and oil that comes to the surface under the natural formation pressure passes through a pressure separator; the wet gas is stripped of its natural gasoline and the dry gas is delivered by a compressor to the oil sand through properly chosen and suitably prepared input wells.

This idea has been labeled: pressure maintenance. Its aim is to keep the oil well's operating pressure at or near the original rock pressure.

The advocates of pressure maintenance on oil wells list numerous advantages for it.

They claim, in the first place, that when the

operating pressure is equal to or greater than the rock pressure the condition of flow approaches that of a well under hydraulic control—the oil will be cleanly swept out of sand cores, perhaps leaving only the irreducible minimum that adheres to the sand grains by surface attraction. In such cases it is likely that there will be no period of flush production followed by a long period of diminishing daily output. Under such a condition the well will pay for itself in a much shorter time, and a short payout is something that every oil operator desires.

Not only will time be saved, but a large and needless expense will be avoided. When the pool has been depleted in the usual manner and a repressuring program has to be confronted, there will generally be little or no gas available to repressure with. The necessary gas has to be bought from outsiders; or upper or lower gas sands on the property have to be tapped; or what gas is available has to be diluted with air; or it may even be necessary to use air alone. But the teaching of experience is against the use of air in a repressuring operation on account of corrosion of pumps and fittings and the possibility of an explosive mixture of gas and air. And when repressuring is started the oil sand will have a vast expanse of empty pore space; and to refill this space with gas under a sufficient pressure to move the residue of oil will take a good deal of time and power. In some repressuring operations results are obtained at once, but in many cases it may be weeks or even months before the residual oil starts to move.

This argument has not been put forward to detract from the merits of repressuring as applied to depleted pools. It has been amply demonstrated that repressuring may be profitable when there is nothing else that can be done, but matters need not be allowed to proceed that far. It will be easier and cheaper and in the end better to start returning the gas to the oil sand at once while it is still plentiful, and while the compressor will need to do but relatively little work in order to keep up the original rock pressure.

And then there is the important matter of conservation. Natural gas that has been popped into the atmosphere is lost forever, both to the oil operator and to the public, but when it is returned under pressure to the pool whence it came it helps the operator produce his oil; and after all the oil has been swept out the pool is still a valuable private asset and public resource, because the high-pressure gas it now contains can be piped away to a market that sooner or later will be available for it.

These are the broad advantages of pressure maintenance as compared with repressuring; both have their places in petroleum technology, but on the whole it will be well to use the one and avoid the other.

Aside from the *a priori* desirability of pressure maintenance its champions list some minor but worth-while operating advantages. The well is more likely to remain in a condition favorable to easy production. For instance, when the oil in the sand is under a high gas pressure much of the gas will be dissolved in the oil. When this gas pressure is dissipated at the well face the gas comes out of solution back in the sand, which thus becomes filled with a non-homogenous gas-oil mixture that moves with more difficulty. The rush of the liberated gas increases sand-cutting on the well fittings, and the tendency for paraffin to separate is said to be enhanced. The high pressure keeps more of the light ends in solution and this may increase the gravity of the crude oil by one or more points, perhaps enough to lift the crude into a higher price bracket. (N. B.—This last point is a highly important one, as will appear further on.) A further advantage imputed to pressure maintenance is that it prevents or delays the encroachment of edge water, which would otherwise invade the oil zone and add to the operator's troubles.

The arguments for pressure maintenance as well as the arguments for repressuring lead to the conclusion that the gas compressor may well be regarded as an essential piece of equipment in many if not most oil fields, either as a means of retrieving past mistakes or of avoiding such mistakes in the first place. Enough is now known to caution the operator who brings in a gassy well to consider thoughtfully what he has to gain by conserving this gas and what he may lose by wasting it. Moreover, the public authorities are realizing what the public loses when the private custodians of the nation's petroleum resources, either ignorantly or through a selfish yearning for quick profits, blithly waste an irreplaceable gift of nature. Already there is some legislation in effect to impose this kind of conservation on the industry.

This idea of pressure maintenance, in which a compressor is used to maintain the original gas pressure of the oil pool from the moment production is started, is relatively new and has not yet been applied to a large number of fields. These fields have shown what advantages may be expected of it, and have also shown what is required of the engineers who inaugurate and maintain the system. These requirements parallel those imposed on the generality of repressuring projects, namely, a careful previous study of the field to disclose all relevant reservoir conditions; to recognize structural features, differences in porosity, saturation and permeability; where to set packers, etc.

There is one category of petroleum deposits where the operator must resort to pressure maintenance as the sole condition under which any production at all can be had. This refers to what are variously described as condensate wells, or distillate oil wells.

These distillate wells represent a new though still a relatively minor phase of the petroleum industry. They are very interesting in many ways; in particular they apply and illustrate a fact that has often been remarked upon; namely, that a long time may elapse between the discovery of important scientific principles and their industrial applications; and that while these principles may be as clear as day to the scientists who know about them, the industries whose operations are involved in these principles go blundering along in inefficiency and waste.

To come to the point, more than fifty years ago the physical chemists had definitely outlined what are called the critical phenomena of liquids and gases. The principle of these critical phenomena was first illustrated by an experiment with carbon dioxide, which at normal temperatures and pressures is a gas. When carbon dioxide is compressed and cooled in a suitable glass vessel its volume shrinks, and as the pressure is increased the gas begins to liquify. If the pressure is now held at that point the liquid and gas phases will continue to exist together. If the pressure is further increased more gas will become liquid and finally all the gas will become liquid. Now, if still more pressure is applied the liquid will begin to become a gas again; it will separate into two layers; the lower layer will consist of liquid and the upper one of gas and there will be a definite line of separation (meniscus) between them. If the pressure continues to increase the liquid layer disappears, and now the carbon dioxide is again completely in the gaseous form.

The above description can be shortened to a statement that by suitably choosing temperatures and pressures any gas may be transformed into a liquid and then by further pressure into a gas. The process is reversible; if the pressure is reduced or the temperature increased, the substance first turns from the gaseous into the liquid state and then into the original gaseous condition.

The temperature at which the liquid will become gas under a certain pressure is called the critical temperature for that pressure, and the pressure needed to gasify the liquid at a certain temperature is called the critical pressure for that temperature.

As we said, these "critical" phenomena were first observed with carbon dioxide and were soon found to be characteristic of all liquifiable gases and all gasifiable liquids. The study of the "critical constants" of gases and liquids became a regular part of all college courses in physical chemistry, but in spite of all this learning it was more than 50 years before anyone had the least notion that it has anything to do with oil pools.

Within the past three or four years it has been amply demonstrated that the critical phenomena of gases and liquids have a great deal to do with oil pools. And now that the fact has become recognized, the wonder is that with so many physical chemists in the land it took such a long time for the connection to be perceived. At any time during the past 50 years a physical chemist acquainted with oilfields, or an oil man acquainted with physical chemistry, might have reasoned as follows:

Much petroleum lies deep in the ground. The temperature of the earth's crust increases with the depth below the surface at a rate such that at 8,000 to 15,000 ft. it may be as much as 220 deg. F. or more, and the oil at these depths will have the same temperature as the rocks. Besides being at these relatively high temperatures, much petroleum is also under great pressure, amounting in extreme

cases to as much as 7,500 or more pounds to the square inch. Now, crude petroleum, when brought to the surface, is a mixture of liquids that can be gasified by heat in a still and of gases that can be liquified under pressure; down in the oil sand where the temperature is high and the pressure is great the gases may not only be condensed to the liquid form, but also may have passed through the critical point and be in the sub-critical gaseous conditions. What is true of petroleum hydrocarbons that ordinarily are gases may also be true of hydrocarbons that ordinarily are liquids; down in the warm nether regions they may have passed through their critical points and are also existing in the sub-critical gaseous condition. If that is the case, all these hydrocarbons in the sub-critical state will behave, not as liquids, but as gases under high pressure. They will move through the oil sand like a gas; they will arrive at the well head in the gaseous form; by reduction of the temperature and the pressure they may be caused to go through their critical points in the reverse direction, and present themselves to the oil producer as salable liquid products.

The first physical chemist who thought along those lines appears to have been Professor W. N. Lacey, who with his associates put this reasoning to the test of experiment on a series of petroleum constituents and found that the theory squared with the facts. Thereby they presented the petroleum technologist with a new working method, and opened for him a rather wide field in which to use it with success if he is fully aware of all the tricks.

The field for application of the new method at present lies mostly in the Gulf Coast region, where there are quite a number of distillate fields in which the hydrocarbons exist in what was at first mistakenly supposed to be the ordinary gaseous condition. These gases were found to be extraordinarily rich in natural gasoline, as much as 18 to 20 bbl. per million cubic feet. When such gas is cooled and relieved of its high pressure the condensate, or "distillate", may contain not only liquid propane and butane but also the whole range of motor fuel constituents, together with kerosene and even heavier hydrocarbons which have come up out of the oil sand while yet in the sub-critical gaseous condition.

It still required some time for the technologists to get a clear picture of the situation. At first they followed the old routine of separating or scrubbing out the liquifiable distillate and popping the dry gas into the atmosphere if no other use could be found for it. In proportion as gas was withdrawn from the producing formation the bottom-hole pressure naturally declined, and with the decline of pressure the amount of distillate in the gas that issued from the well head declined from 20 bbl. per million cubic feet to 15, then to 10, and on down toward a point where the project was certain to fizzle out.

About this time the technologists, who at first were inclined to pooh-pooh the theory of the critical states of hydrocarbons in oil sands, began to listen respectfully to Professor Lacey and his associates. The falling-off of the content of distillate in the gas was clearly a consequence of the loss of formation pressure. The hydrocarbons in the oil sand were in the sub-critical gaseous condition because they were at the temperatures and under the pressures that kept them in that condition; but as the formation pressure was dissipated they would come out of the sub-critical state and assume the liquid form, first the heavier and then the lighter fractions as they passed again through their respective critical points of pressure.

From the standpoint of the oil producer this transition is distinctly an unhappy one. On passing from the gaseous to the liquid form the hydrocarbons lose their mobility. Being now liquid, they wet the sand grains and stick fast to them; generally a distillate sand does not contain a quantity of hydrocarbons great enough to provide the conditions for hydrostatic flow toward the bore hole. The upshot is that while hydrocarbons are recoverable as long as they are gaseous and mobile, they are irrecoverable when liquid and immobile.

The operator's recourse now suggests itself. Keep the operating pressure on the distillate sand always well above the critical pressure. In other words, pressure maintenance on distillate pools is mandatory. The hydrocarbons must be kept as closely as possible under the original rock pressure until they have safely passed through the well head. At least, no reduction of pressure should be allowed to occur back in the producing sand where the liquid will stick to the sand grains. If some condensation takes place during the upward passage through the casing, little or no harm will be done; the condensate will drop back to the bottom of the well, from whence it may be recovered through the tubing which is left in place for that purpose.

The operating scheme of a distillate pool is relatively simple in principle although there are innumerable details that vary according to the geological, physical and economic conditions affecting each project. The gas under high pressure is led through one or more pressure separators, where the pressure is reduced to a point conveniently below the critical point; at the same time its temperature is reduced by expansion, which may be supplemented by artificial cooling. The combined effect of temperature and pressure reduction is to liquify these hydrocarbons that can exist as liquids under low pressures and temperatures. The temperature of the wet gas may be lowered well below nine deg. F. by artificial refrigeration, and the lower the temperature is brought the greater will be the percentage of recovery. However, the operator of a distillate well who resorts to extreme refrigeration must take precautions against gas hydrates that would choke his lines; this detail is now well understood.

Another method of condensate recovery that is proving more efficient than refrigeration is high pressure absorption. With higher recoveries, lower costs and the fact that necessity for subsequent heating is eliminated, absorption may soon entirely displace refrigeration. Efficiency improvement of the order of eight to ten percent are said to be common where high pressure absorption systems are installed in preference to the refrigeration.

After the gas has been stripped of the liquifiable products that can be economically obtained it is sent through a compressor back to the formation at somewhat above the existing rock pressure. This return of the gas is called cycling. In order to minimize the cost of recompressing the gas, the pressure in the operating stage of the process is lowered as little as possible consistent with a satisfactory percentage of recovery.

Now that the theory of the critical state of hydrocarbons in oil sands has become well understood; certain previously obscure facts and observations acquire an explanation. In many if not most repressuring projects applied to depleted oil sands it has been noticed that the amount of natural gasoline brought up with the recycled gas shows an increase; it has even been noted that the total quantity of gas increases; and that the percentage of heavier fractions such as kerosene that reaches the surface in gaseous form tends to increase. The explanation is that the increased pressure supplied by the compressed dry gas sent down from the surface provides a necessary condition for forcing some of the residual oil in the sand into the sub-critical gaseous state. Perhaps the same natural gasoline, kerosene, etc., found in recycled gas originally existed in the sub-critical state before the original rock pressure was thoughtlessly dissipated.

Experts who have delved into the history of the Kettleman field in California and the Oklahoma City field have reached the conclusion that these large petroleum deposits were originally under pressure and temperature such that a considerable proportion of their contents were in the sub-critical gaseous state; that is, they were combination oil and distillate pools, with an upper gas zone above a liquid oil zone. It is said that if the pressure on these two fields had been maintained by cycling, vast amounts of natural gasoline and even motor fuel might have been obtained. But in those days the operators of those fields knew nothing about critical states and recycling operations; the only use they had for a compressor was to pump what dry gas they could to consuming centers; the rest could be thrown away. The consequence was that their formation pressures declined to a point where the valuable light hydrocarbons came out of the sub-critical state (retrograde condensation) and mingled with the general fluid contents of the pools. Superficially considered, this might not be supposed to represent a loss, as the liquid may still be subject to recovery by pumping or by an eventual repressuring. But there is a hitch. A hydrocarbon that exists in the sand in the sub-critical state is mobile and is 90 or more percent recoverable by rational pressure maintenance. On the other hand, even under the very best conditions hardly 50 or 40 percent of the liquid contents of an oil reservoir are recoverable by any generally available means; the rest wets the sand grains and sticks.

It is now known that there is a goodly number of such combination oil pools.

UNDERGROUND Storage For National Defense

By B. Orchard Lisle

U. S. Government Undertakes Financial Burden of Storing Huge Quantities of Aviation Gasoline Through Formation of Defense Supplies Corporation and Revolving Pool — Technical Problems Yet to be Solved Due to Lack of Experience With Subsurface Tankage.

ONE of the latest events in the American National Defense program has been the provision of facilities whereby large quantities of aviation gasoline may be stored as a wartime reserve. Lacking the experience necessary for such a venture, the government has asked the co-operation of leading oil companies having the experience and organization to carry out the scheme. This has been but one of a sequence of inter-related moves to ensure security of military supplies.

First came the demand for a defense force of 50,000 fighting planes—which, in turn, brought to the forefront the problem of aviation fuel supplies. America's oil industry is more than capable of supplying wartime demand for 100 octane spirit required by present military forces, but some additional construction might be required to meet the greater requirements of the enlarged air fleet.

The recent move to limit exports of aviation fuel to the Western Hemisphere could not be considered adequate to ensure building-up of large reserves of this class of fuel: perhaps the government felt that it might have an opposite effect. Other than Pan-American Airways there is but a small demand by commercial aircraft for 100 octane fuel, and the major customers are the Army and Navy air forces. Oil company executives owe allegiance to their stockholders, and without existence of a substantial market could not be expected to permit continuation of high-test fuel production merely to put it in storage tanks (which would have to be specially built for this purpose).

Some plant expansion will be required to enable the supply of the 17,400,000 bbl. of aviation gasoline which it has been estimated will be necessary for maintenance of the expanded air arm on a peacetime preparedness basis—more than twelve times the 1939 purchases by the government. Immediate expansion of productive capacity for 100 octane gasoline and synthetic blending agents is required, but the question of financing must be considered. It has been pointed out already that there is but a minor market demand, so the investment would be economically unsound unless the government grants long-term purchase contracts or compensates investors in some other manner. However, the government seems to have been avoiding any direct concession along these lines.

If, on the other hand, the quantity of high-test fuel in storage could be increased it would be possible to hold back for a while on the construction of some of the additional refining plant. Such storage would have to be on a large-scale basis, while refinery expansion necessarily would be carried out over a wide area.

One of Dr. Wilson's first official statements was relative to his request for accumulation of minimum stocks of 1,000,000 bbl. of aviation fuel, working up to a maximum of 10,000,000 to 20,000,000 bbl. This proposed reserve, 70 percent of which would consist of 100 octane grade, would be partly in underground storage facilities, he indicated. A number of technical problems remain to be solved before this can be fully effected, it is reported, but the machinery at Washington has been set in motion.

A special committee of oil company engineers has been established by the Defense Commission to advise on storage systems. The members, working without compensation from the government, include: Scott E. Drummond, of Jersey Standard; E. D. Seymour, of Socony-Vacuum; S. P. Johnson, of California Standard; C. D. Norris, of The Texas Co.; Walter Samans, of Sun Oil; W. E. Engelbrecht, of Phillips Petroleum, and O. B. Lewis, of Ethyl Corp.

Reconstruction Finance Corporation has announced the creation of Defense Supplies Corporation, capitalized at $5,000,000, to acquire and store high-test aero fuel, and it is intended to aid the Defense Commission as well as the Navy and War Departments in the national defense program.

Defense Supplies Corporation has been allotted $50,000,000 by the R. F. C. for the acquisition of a substantial supply of high octane gasoline for storage at points strategic to Army and Navy air bases, throughout the country. The R. F. C. is to finance purchase of the fuel, while the military departments are to finance construction of the storage facilities to care for it.

Secretary of Navy Knox has testified that the Defense Commission earnestly recommended creation of this storage pool, adding that "the Navy's share in the cost of establishing storage facilities for that pool of 7,500,000 bbl. is $2,500,000" and that the Army would put up $5,000,000.

He estimates that the revolving pool would hold a steady reserve supply for three to four months of actual combat. The R. F. C. end of the project will be self-liquidating, it was explained, as the Army and Navy will buy their gasoline requirements from the pool, R. F. C. making a surcharge on the fuel so acquired; as they take delivery, R. F. C. will purchase an additional amount to keep the stored reserve at parity.

Almost simultaneously with formation of Defense Supplies Corporation, the Senate Appropriations Committee reported the $5,000,000,000 supplemental defense appropriations bill, adding among other items $3,000,000 for storage of aviation gasoline. Hearings before the committee revealed that it is planned to build storage installations throughout the country for this purpose, underground tanks having been agreed upon by defense officials as safer from attack and not much more expensive than surface storage.

Technically, the difficulties are not insurmountable. Storage of even the most volatile products offers no serious difficulties in a temperate climate, while even during midsummer heat waves, the thickness of the earth above would in some measure act as insulation. Since only one product is involved, there appears to be no need for any elaborate system of tankage and pipelines.

Opinion as to the best form that could be taken by this storage varies somewhat. There are some who believe that ordinary steel surface tanks, camouflaged by dazzle-painting, would suffice because any fire caused by a direct hit could be confined to a single tank. However, the main purpose behind the scheme is to have hidden reserves which cannot be discovered by an enemy, and even when so camouflaged such installations are readily picked out by aerial cameras because of the shadows cast by the tanks themselves. Once they are spotted by reconaissance planes, the dive bomber is presented with a true target—each tank and surrounding fire-wall forming a perfect bulls-eye. This ability to pick out ordinary installations has been shown by the photographs taken at high altitudes by the German Air Force over such installations as Thameshaven. But, as yet no photographs have been released showing the underground storage installations built by the British at Purfleet and in other parts of England.

The surface type of storage already in use has been virtually eliminated from U. S. government plans, but it is not certain whether sunken tanks or buried storage will be more extensively employed.

Sunken storage involves a partial excava-

tion for the tank, the earth removed being piled around and thinly over the top in such a manner that no shadow is cast on the ground. Such installations are not likely to be spotted from great heights, but espionage agents on the ground or low-flying scout planes could pick out the suspicious contours of these wart-like mounds readily from their regular spacing adjacent to air bases. Cultivation on the covering earth would help in disguising these, but not adequately. They would serve as a fair compromise, and should a direct hit be made the surrounding earth to some extent would act as a fire-wall.

There is little doubt that the most effective form of camouflage will be to hide the tanks completely, leaving no indication of their presence visible from the surface. Such is the case with underground or buried storage installations.

Some authorities feel that any scheme for emergency storage must be elastic, universal and capable of being undertaken at once and completed rapidly; to meet these specification it has been suggested that huge concrete reservoirs just below surface level would be desirable. Such storage has been built above-ground in California, with capacities as great as 1,000,000 bbl. each. With a three-foot thickness of earth above, small trees and underbrush could be planted which would give the installation a natural appearance within a few months of its completion.

Location of the storage no doubt will be convenient to existing trunk pipelines, railway systems or inland waterways, so that replenishment of the reserves will be simplified; at the same time convenience to air bases is of primary importance. In selecting actual sites for construction the price of land will be a consideration, while it is desirable that the natural contours be such that pumping problems will not be very great while use of basin-like surface formations will not only facilitate the later creation of a natural appearance to the terrain but will also act as its own fire-wall.

The main advantage of buried storage over the dungeon type of underground storage is that the former is but slightly more expensive than surface storage, while the latter costs about 250 percent more than surface tanks. To be proof against heavy aerial bombs and large calibre shells, it would have to be deep indeed, but the reservoir about three feet below the surface would be fairly safe from all but a direct hit. A 200 lb. bomb falling at a distance upon an overground tank farm would generally suffice to dislocate one or more plates and cause leakage which would spell trouble when small-calibre incendiary bombs followed through. Opinion differs as to the effect of such a miss where buried storage is involved; some claim that the surrounding earth would break the shock, while others maintain that the concussion would be transmitted to the sub-surface tank.

However, as already explained, the purpose of the thin layer of earth is to hide it from discovery rather than to afford an adequate protection against actual aerial attack.

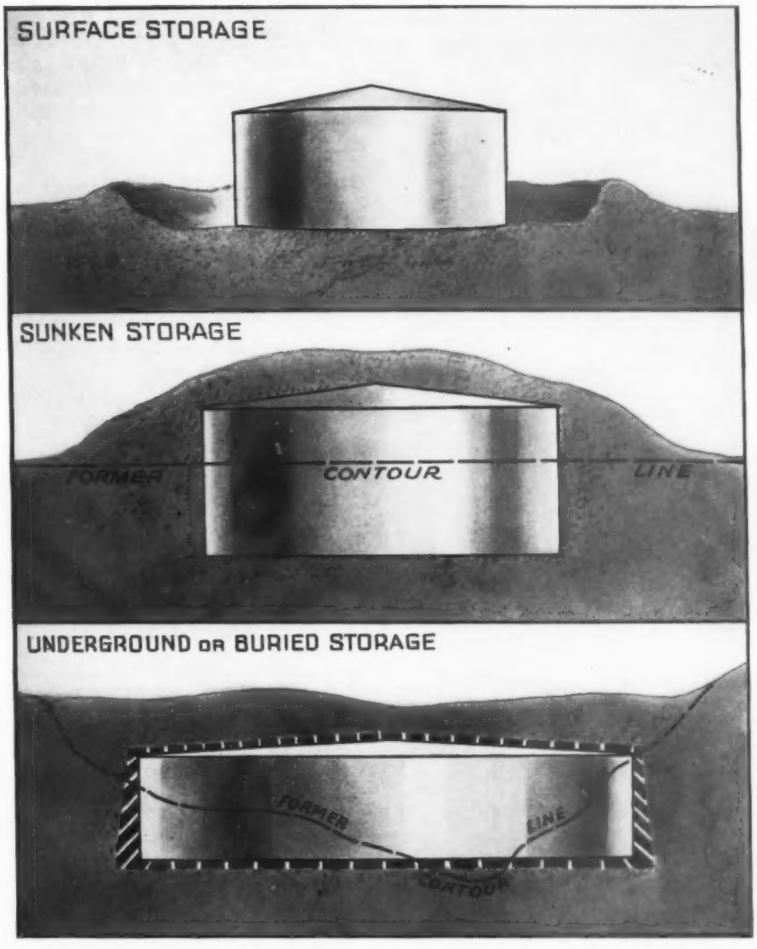
Use of steel tanks in direct contact with the earth is open to debate, as some provision would have to be made for external as well as internal corrosion. This naturally suggests the use of reinforced concrete reservoirs, perhaps provided with a steel lining which could be appreciably thinner than the plates used for surface storage tanks. The reduced weight in steel required would cut down on the cost of construction. The French armaments concern Schneider et Cie. built a large number of underground installations with and without steel facing both at shallow depths and in natural caverns formed by abandoned quarries, mines, etc., between 1936 and the beginning of the European War. These were said to have been quite satisfactory, as the concern had solved the problems of the hydrocarbons attacking the concrete and creation of perfect contact between the steel lining and the concrete. Of course, one of the most serious drawbacks of the sub-surface tank is the difficulty of inspection in case a leak occurs; this is especially dangerous with a product like gasoline.

Likewise, opinion differs as to whether or not the pipeline system should likewise be below the surface or lying above ground. Some maintain that, with the lines on top, repairs due to leakage or attack can be more easily repaired; that overground pipe is reasonable flexible and would not be injured except by direct hit or by a splinter, whereas if run a few feet underground concussion would render it more liable to damage and that tracing and repairing a leak would be more difficult—as well as being expensive. Also, that to make such pipe immune by laying it deep would be extremely costly.

It is believed that much of the emergency storage in England has surface pipe, whereas in France great success has been reported with buried lines, while some of these ducts have been constructed of concrete piping.

In either case, a bomb would leave adequate indication as to where it had struck, and if valves are placed at regular intervals the loss would be minor. Repair could be completed in about twelve hours by a good welding crew. A temporary flexible rubber hose connection could be put up in even less time, if necessary.

There seems much to be gained by way of national defense fuel reserves by the government's scheme for sub-surface storage of aviation gasoline. Cultivation of the ground above will in a short time restore the area to its former appearance and conceal the reservoirs beneath. Service building will be visible but the best camouflage for these is to eliminate any characteristic feature and to build them along the lines of architecture prevalent in the particular district.



Foreign Oil Legion

JUAN PARIS HIJO has been appointed Director of Mines, in the Ministry of Fomento at Caracas, Venezuela.

* * *

Edward L. Steiniger, Venezuelan Petroleum Co., and Mrs. Steiniger as they sailed from New York late in September for Venezuela on board the Santa Rosa.

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Left to right below, J. Britton, John Stump, C. M. Davidson and K. Patterson of the Jersey Standard.

© Robert Yarnall Richie

John Evans of Lucy Export, and Gene Trammell of the New York chapter of the Nomads at a recent outing at Englewood.

CLARENCE DAVIDSON, JOHN STUMP, J. BRITTON and KEN PATTERSON of the Standard Oil Company, N. J. gave their annual clambake to brother oil men at Babylon, L.I. on September 17, prior to the convention of the National Petroleum Association at Atlantic City, many of them proceeding to this New Jersey seaside resort directly from the clambake. About 200 oil men from various parts of the world attended and had an enjoyable time.

Paul L. Hopper

PAUL L. HOPPER, Chief of the Fuel Section, Department of Commerce in Washington, D. C. has been commissioned as a Lieutenant of the Navy in the Bureau of Engineering in the Navy Department. Mr. Hopper was representative of the Department of Commerce at Calcutta, India, from 1930 to 1933 after which he returned to Washington to serve in the Department of Commerce. The statistical work performed by the Fuel Section of the Department brought Mr. Hopper into contact with many of the members of the oil industry.

David Shephard at the Babyon clambake.

DAVID SHEPHARD, technical consultant to International Association (Petroleum Industry) Ltd. of London, is now back in the United States, and is located at the New York office of the Standard Oil Company, N. J.

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Dr. Rudolf Shider, geological department of Asiatic en route to Venezuela on September 14.

W. Richison Schofield

W. R. SCHOFIELD, formerly chief engineer of Leeds and Northrup Company of Philadelphia has recently been appointed director of engineering. JOHN W. HARSH, formerly chief assistant engineer, has been advanced to the position formerly filled by Mr. Schofield and JOHN F. QUEREAU now occupies Mr. Harsh's former position.

* * *

HOWARD PAGE, formerly assistant manager of refinery operations in Europe for the Standard Oil Company, N. J. is now in the economics division of the company in New York. He returned from London on the last transatlantic voyage of the SS WASHINGTON.

DEWEY E. JOHNSON has recently been appointed general superintendent of the Caripito refinery of the Standard Oil Company of Venezuela. Mr. Johnson, who is now in Venezuela made a trip to New York, a few weeks ago, following the death of P. J. KELLY, former general superintendent of the new Caripito plant. Mr. Johnson has served with the Jersey organization for twenty years, working for several years in refineries in the United States and later being transferred to Tampico, Mexico. In 1928 he became general superintendent of the Maracaibo refinery of the West India Oil Company and more recently has been in charge of the La Salina plant of the Lago Company.

* * *

LIEUTENANT HENRY DETERDING, son of the late Sir Henri Deterding of the Royal Dutch Shell group was recently reported missing while on active service with the fleet air-arm of the British navy.

John W. Harsch

Ralph Porter and L. E. Bushard snapped by Bill Bettis at the Los Angeles Nomads barbecue.

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G. K. Kaufman, geologist of the Standard Oil Co. of Venezuela on the deck of the Santa Paula in New York harbor just before sailing for Venezuela.

DR. C. N. LANNING, European manager of refinery operations of the Standard Oil Company, N. J. is on vacation following his recent return from the war zone of London. Dr. Lanning is due back at the New York office of the company.

* * *

CLARENCE MORRIS, founder and publisher of Petroleum Engineer died September 18th of a heart attack while at his home in Los Angeles.

* * *

ON September 11th, the first of a series of regular annual barbecues was held by the Los Angeles chapter of the Nomads. Over two hundred and fifty Los Angeles Nomads and some ninety-six oil men who had seen service in foreign oilfields attended the first of these barbecues. The next regular meeting of the Los Angeles Nomads was scheduled for October 9th and it was expected that several prominent foreign operators will be in attendance at this meeting.

F. C. Ripley and A. E. Fowkes at the barbecue.

WORLD OIL P

All figures furnished direct to WORLD PETROLEUM by governments, except where otherwise specified

U. S. BARRELS

	Sept. 1939	Oct. 1939	Nov. 1939	Dec. 1939	Jan. 1940	Feb. 1940	March 1940	April 1940	May 1940	June 1940	July, 1940	Preliminary Figures August, 1940
United States	108,168,000	114,197,800	111,887,000	114,808,500	113,140,700	108,668,800	120,075,000	116,046,000	118,283,000	111,690,000	113,244,000	108,526,330
Soviet Union[4]	18,000,000	18,406,932[1]	17,813,160[1]	18,406,932[1]	18,406,932[1]	17,251,723[1]	18,454,796[1]	17,896,740[1]	18,448,875[1]	17,853,750[1]	18,448,875[1]	18,448,875
Venezuela	18,652,354	19,516,845	16,681,881	16,050,535	14,798,667	14,380,134	15,514,962	16,495,995	18,343,406	18,629,609	16,580,129[1]	16,699,669
Iran[5]	6,423,390[1]	6,637,503[1]	6,423,390[1]	6,637,503[1]	6,637,503[1]	6,227,895[1]	6,745,073[1]	6,507,180[1]	6,560,000[1]	6,449,520[1]	6,664,504[1]	6,664,504
Netherland India: Sumatra	3,502,437	3,600,371	3,427,490	3,629,655	3,472,786	3,149,536	3,440,792[1]	3,428,880[1]	3,456,624[1]	3,345,120[1]	3,456,624[1]	3,456,624
Borneo	865,693	995,207	1,068,349	1,086,713	1,093,743	1,062,210	1,097,516[1]	1,063,890[1]	1,106,080[1]	1,070,400[1]	1,106,080[1]	1,106,080
Java[9]	511,355	556,658	549,926	633,136	561,064	507,207	562,665[1]	537,720[1]	555,582[1]	537,660[1]	555,582[1]	555,582
Molucca[*]	68,065	64,292	62,340	60,550	59,215	62,340	54,021[1]	67,740[1]	62,310[1]	60,300[1]	62,310[1]	62,310
Roumania	3,795,308	3,842,567	3,743,041	3,842,154	3,786,908	3,595,888	3,818,554	4,422,721	3,830,236	3,839,640[1]	3,967,628[1]	3,967,628
Mexico[15]	4,050,000	4,500,000	3,700,000	3,500,000	3,348,682	3,147,385	3,286,000	3,180,000	3,412,000	3,873,720	2,945,000	3,410,000
Iraq	2,530,770[1]	2,615,129[1]	2,530,770[1]	2,615,129[1]	2,615,129[1]	2,461,723[1]	2,666,713[1]	2,578,020[1]	2,644,362[1]	2,559,060[1]	2,644,362[1]	2,644,362
Colombia	1,894,941	1,860,620	1,918,891	1,871,594	2,484,398	2,025,618	2,203,272	2,192,178	2,427,000	2,236,650[1]	2,311,205[1]	2,311,205
Trinidad	1,583,850[1]	1,636,645[1]	1,583,850[1]	1,636,645[1]	1,636,645[1]	1,529,808[1]	1,633,421[1]	1,580,940[1]	1,634,754[1]	1,582,020[1]	1,634,754[1]	1,634,754
Argentine	1,542,755	1,632,997	1,621,927	1,691,123	1,751,910	1,797,072	1,686,338	1,620,360	1,688,942	1,682,520	1,741,983[1]	1,741,952
Peru[3]	1,116,810[1]	1,154,037[1]	1,116,810[1]	1,154,037[1]	1,154,037[1]	1,071,869[1]	1,139,932[1]	1,097,400[1]	1,143,466[1]	1,106,580[1]	1,143,466[1]	1,142,466
Bahrein[6]	647,595	571,673	563,985	632,962	631,644	581,255	636,577	579,078	616,174	602,560	620,486	621,116
Burma[7]	685,756	710,501	753,771	708,054	666,810[1]	629,039[1]	689,750[1]	666,810[1]	679,520[1]	657,600[1]	679,520[1]	679,520
Canada[3]	720,866	816,257	731,209	502,920	486,859	655,586	570,131	634,869	676,486	657,098	877,133	877,133
Brunei[3]	473,010[1]	488,777[1]	473,010[1]	488,777[1]	488,777[1]	456,576[1]	487,661[1]	471,540[1]	487,940[1]	472,200[1]	487,940[1]	487,940
Great Germany: Old Reich[14]	368,820[1]	381,114[1]	368,820[1]	381,114[1]	381,114[1]	360,383[1]	386,508[1]	371,610[1]	384,183[1]	371,790[1]	384,183[1]	384,183
Ostmark[13]	56,970[1]	58,869[1]	56,970[1]	58,869[1]	58,869[1]	57,072[1]	61,721[1]	61,230[1]	61,194[1]	59,220[1]	61,194[1]	61,194
Slovakia and Moravia	9,810[1]	10,137[1]	9,810[1]	10,137[1]	10,137[1]	9,454[1]	10,106[1]	9,780[1]	10,106[1]	9,780[1]	10,106[1]	10,106
Poland	320,370[1]	331,049[1]	320,370[1]	331,049[1]	331,049[1]	310,155[1]	331,669[1]	320,790[1]	331,421[1]	320,730[1]	331,421[1]	331,421
Japan[16]	222,513	223,016	224,494	223,960[A]	225,308[1]	210,801[1]	224,068[1]	216,960[1]	224,719[1]	217,470[1]	224,719[1]	224,719
British India[11]	212,322	229,422	213,270	228,281	197,532[1]	180,351[1]	189,999[1]	180,090[1]	191,611[1]	185,430[1]	191,611[1]	191,611
Ecuador	193,720	193,382	196,808	205,138	204,509	188,024	211,610	208,513	213,000	201,650	207,700	210,676
Saudi Arabia	538,136	512,590	313,757	437,020	491,663	323,416	606,201	476,359	334,728	356,571	478,243	425,829
Sarawak[12]	109,080[1]	112,716[1]	109,080[1]	112,716[1]	112,716[1]	104,951[1]	112,282[1]	108,330[1]	112,282[1]	108,660[1]	112,282[1]	112,282
Egypt[13]	362,880	420,519	434,174	446,846	438,367	376,043[1]	432,729[1]	454,260[1]	435,891[1]	421,830[1]	435,891[1]	435,891
Italian Empire: Albania[18]	114,540[1]	118,358[1]	114,540[1]	118,358[1]	118,358[1]	112,230[1]	123,411[1]	119,250[1]	121,241[1]	117,330[1]	121,241[1]	121,241
Italy	7,736[1]	7,750[1]	7,500[1]	7,750[1]	7,750[1]	7,250[1]	7,657[1]	7,380[1]	7,688[1]	7,440[1]	4,400[B]	4,400
France	42,653[1]	42,470[1]	41,160[1]	42,532[1]	42,532[1]	39,817[1]	42,439[1]	41,100[1]	42,470[1]	41,100[1]	42,470[1]	42,470
Hungary	65,210[1]	65,317[1]	65,210[1]	65,317[1]	65,317[1]	62,350[1]	67,580[1]	65,580[1]	66,805[1]	64,650[1]	164,000[B]	164,000
Bolivia	7,893[1]	8,556[1]	8,280[1]	8,556[1]	8,556[1]	7,975[1]	8,587[1]	8,310[1]	8,556[1]	8,280[1]	8,556[1]	8,556
Other Countries[17]	50,000	49,073	47,490	49,073	49,073	45,849	49,786	48,150	49,383	47,790	49,383	49,383
WORLD TOTAL	177,915,608	186,599,149	179,182,533	182,683,635	179,965,259	171,657,785	187,629,427	183,665,753	188,652,035	181,445,728	181,998,981	177,817,032

[A] Estimated official sources.
[1] Estimated W. P.
[*] Includes natural gasoline (naphtha) production.
[3] International Petroleum Company and Lobitos Oilfields, Ltd. figures combined.
[B] Reliable sources indicate large increase in Hungary's production and decrease in Italy's.
[4] Russian Saghalin included with U.S.S.R.
[5] Anglo-Iranian Oil Company, Ltd., figures revised —fuel oil returned to the ground has been deducted.
[6] Bahrein Petroleum Company, Ltd., figures.
[7] Does not include Assam or Punjab, which are listed together under British India.
[8] British Malayan Petroleum Company, Ltd., figures.
[9] Includes Madura.
[*] Includes all other Netherland India.

Daily Averages in Barrels

	Jan.—August 1940	Jan.—August 1939
United States	3,728,171	3,354,703
Soviet Union	595,125	593,004
Venezuela	538,699	555,070
Iran	214,984	214,113
Netherland India: Sumatra	111,504	112,745
Borneo	35,680	37,118
Java	17,922	17,768
Molucca	2,010	2,347
Roumania	127,988	126,373
Mexico	109,027	97,440
Iraq	85,302	84,359
Colombia	74,555	59,631
Trinidad	52,734	52,795
Argentine	56,192	50,325
Peru	36,886	37,227
Bahrein	20,032	21,285
Burma	21,920	20,263
Canada	22,275	20,848
Brunei	15,740	15,812
Great Germany: Old Reich	12,393	12,294
Ostmark	1,974	1,899
Slovakia and Moravia	326	327
Poland	10,691	10,679
Japan	7,249	7,238
British India	6,181	5,929
Ecuador	6,744	6,267
Saudi Arabia	14,315	8,449
Sarawak	3,622	3,641
Egypt	14,061	12,096
Italian Empire: Albania	3,911	3,818
Italy	221	249
France	1,370	1,367
Hungary	2,951	2,098
Bolivia	276	278
Other Countries	1,593	1,573
WORLD TOTAL	5,954,229	5,551,259

Official Crude Oil Production Figures for 1933 to 1939 (Revised) in Barrels

	1939	1938	1937	1936	1935	1934	1933
United States	1,264,256,000	1,214,355,000	1,279,160,000	1,098,516,000	996,596,000	908,065,000	905,656,000
Soviet Union	216,727,024	206,192,000	201,856,661	199,635,921	184,008,033	175,635,783	155,596,429
Venezuela	205,783,585	188,429,050	187,675,477	155,270,840	148,809,057	136,098,681	117,113,940
Iran	78,151,332	78,320,840	78,109,001	62,977,950	57,520,488	57,902,092	54,440,675
Netherland India: Sumatra	41,557,020	34,538,128	33,451,511	30,469,428	28,004,595	26,336,011	22,345,172
Borneo	13,125,425	12,812,383	12,960,072	13,068,910	13,529,185	14,335,543	15,003,175
Java	6,568,660	6,955,283	7,152,931	3,618,293	3,462,440	3,778,920	3,600,816
Molucca	836,144	607,622	537,436	375,823	311,872	273,698	285,335
Roumania	45,931,846	48,366,000	52,395,725	63,532,846	61,270,072	61,849,306	53,919,700
Mexico	39,428,141	38,505,824	46,455,687	41,027,915	40,240,563	38,171,946	34,000,830
Iraq	30,791,132	32,404,000	30,603,660	29,913,150	27,410,983	7,639, 84	1,094,915
Colombia	22,036,613	21,581,588	20,297,543	18,756,110	17,597,655	17,337,900	13,156,126
Trinidad	19,270,256	17,736,176	15,502,989	13,237,030	11,671,224	10,894,363	9,561,353
Argentine	18,613,167	17,076,237	16,354,717	15,457,960	14,297,025	14,021,901	13,690,556
Peru	13,587,906	15,908,279	17,459,112	17,593,069	17,056,555	16,314,381	13,257,310
Bahrein	7,588,554	8,297,998	7,762,264	4,644,635	1,264,807	285,072	31,377
Burma	7,872,981	7,499,498	7,847,553	7,587,718	7,181,113	7,278,859	7,114,311
Canada	7,837,503	6,965,457	2,996,033	1,507,931	1,447,204	1,410,895	1,145,333
Brunei	5,755,164	5,387,214	4,397,038	3,296,938	3,302,905	2,705,350	2,035,656
Great Germany: Old Reich	4,487,491	3,850,044	3,148,300	3,076,858	2,967,438	2,204,402	1,656,602
Ostmark	693,247	370,038	221,266	50,092	44,347	27,965	5,765
Slovakia and Moravia	119,380	132,005	123,474	126,603	136,580	177,797	121,695
Poland	3,898,044	3,828,438	3,799,862	3,869,575	3,901,881	4,011,336	4,174,079
Japan	2,652,930	2,511,184	2,487,841	2,403,072	2,294,878	1,872,837	1,504,412
British India	2,332,467	2,330,209	2,161,653	1,978,329	2,037,810	1,921,863	1,628,803
Ecuador	2,312,118	2,257,278	2,161,436	1,942,467	1,731,785	1,636,619	1,619,902
Saudi Arabia	3,933,904	495,135	64,968	19,777	Nil	Nil	Nil
Sarawak	1,327,327	1,624,882	1,655,565	1,547,882	1,776,593	1,942,591	2,206,815
Egypt	4,602,797	1,561,231	1,163,267	1,262,666	1,255,151	1,527,252	1,653,535
Italian Empire: Albania	1,393,727	437,597	380,292	219,693	41,218	17,500	11,437
Italy	91,330	106,083	112,700	129,653	128,615	162,449	213,534
France	500,815	516,240	507,067	534,063	529,664	700,000	786,346
Hungary	769,092	330,829	13,910	100	Nil	Nil	Nil
Bolivia	100,885	106,620	123,123	104,746	163,295	157,875	111,973
Other Countries	578,036	243,000	70,000	37,100	32,300	64,000	54,100
WORLD TOTAL	2,075,512,043	1,982,639,390	2,041,170,134	1,797,791,150	1,652,023,331	1,516,760,036	1,438,797,443

PRODUCTION

Figures in U. S. barrels of 42 gal.—Conversion ratios used are weighted averages for individual countries

METRIC TONS

	Sept. 1939	Oct. 1939	Nov. 1939	Dec. 1939	Jan. 1940	Feb. 1940	March 1940	April 1940	May 1940	June 1940	July, 1940	Preliminary Figures August, 1940
United States	14,635,096	15,450,953	15,138,276	15,533,757	15,307,901	14,702,854	16,246,164	15,700,987	16,003,653	15,111,622	15,321,877	14,683,581
Soviet Union[4]	2,300,000	2,508,024[1]	2,427,120[1]	2,508,024[1]	2,508,024[1]	2,360,194[1]	2,531,522[1]	2,436,780[1]	2,520,083[1]	2,438,790[1]	2,520,083[1]	2,520,083
Venezuela	2,769,466	2,897,824	2,476,894	2,383,153	2,197,278	2,135,135	2,303,632	2,449,294	2,723,594	2,766,089	2,461,786[1]	2,479,535
Iran[5]	852,090[1]	880,493[1]	852,090[1]	880,493[1]	880,493[1]	826,152[1]	894,753[1]	863,190[1]	870,212[1]	855,540[1]	884,058[1]	884,058
Netherland India: Sumatra	448,398	460,936	438,803	464,685	444,602	403,218	440,506[1]	438,960[1]	432,525[1]	426,270[1]	440,479[1]	440,479
Borneo	110,830	127,411	136,775	139,126	140,026	135,989	140,509[1]	136,290[1]	141,608[1]	137,040[1]	141,608[1]	141,608
Java[5]	65,466	71,266	70,404	81,057	71,830	64,935	72,035[1]	68,820[1]	71,114[1]	69,210[1]	71,114[1]	71,114
Molucca[5]	8,842	8,231	7,981	7,752	7,581	7,981	6,916[1]	8,670[1]	7,967[1]	7,710[1]	7,967[1]	7,967
Roumania	514,618	521,026	507,531	520,970	513,479	487,578	517,770	599,691	519,354	520,620[1]	537,974[1]	536,517
Mexico[10]	594,713	660,973	543,318	513,950	492,094	462,171	482,525	466,960	501,028	491,923	432,452	500,734
Iraq	338,280[1]	349,556[1]	338,280[1]	349,556[1]	349,556[1]	330,034[1]	356,531[1]	344,670[1]	353,741[1]	342,330[1]	353,741[1]	353,741
Colombia	264,287	257,920	267,627	260,524	346,499	282,512	307,290	305,745	338,493	311,940[1]	322,338[1]	322,338
Trinidad	222,780[1]	230,206[1]	222,780[1]	230,206[1]	230,206[1]	215,151[1]	229,710[1]	222,360[1]	229,896[1]	222,480[1]	229,896[1]	229,896
Argentine	219,765	232,620	231,043	240,900	249,559	255,993	240,219	230,820	240,590	239,675	248,145[1]	248,141
Peru[5]	147,810[1]	152,737[1]	147,810[1]	152,737[1]	152,737[1]	141,810[1]	150,784[1]	145,200[1]	151,280[1]	146,400[1]	151,280[1]	151,280
Bahrein[5]	87,030	78,012	76,963	86,375	86,195	79,319	87,017	79,022	84,084	82,227	84,673	84,754
Burma[5]	94,717	98,135	104,112	97,797	92,101[1]	86,855[1]	94,147[1]	91,980[1]	93,527[1]	90,510[1]	93,527[1]	93,527
Canada[5]	91,736	103,875	93,052	64,001	61,957	83,429	72,554	80,792	86,088	83,621	111,619	111,619
Brunei[5]	63,090[1]	65,193[1]	63,090[1]	65,193[1]	65,193[1]	60,900[1]	65,038[1]	62,880[1]	65,069[1]	62,970[1]	65,038[1]	65,038
Great Germany: Old Reich[14]	53,190[1]	54,963[1]	53,190[1]	54,963[1]	54,963[1]	51,997[1]	55,800[1]	53,940[1]	55,490[1]	53,700[1]	55,490[1]	55,490
Ostmark[15]	9,030[1]	9,331[1]	9,030[1]	9,331[1]	9,331[1]	9,048[1]	9,827[1]	9,780[1]	9,703[1]	9,390[1]	9,703[1]	9,703
Slovakia and Moravia	1,550[1]	1,519[1]	1,470[1]	1,519[1]	1,519[1]	1,421[1]	1,519[1]	1,470[1]	1,519[1]	1,470[1]	1,519[1]	1,519
Poland	42,960[1]	44,392[1]	42,960[1]	44,392[1]	44,392[1]	41,644[1]	44,516[1]	43,050[1]	44,454[1]	43,020[1]	44,454[1]	44,454
Japan[10]	31,651	31,723	31,933	31,857[A]	32,178[1]	30,131[1]	32,023[1]	31,020[1]	32,085[1]	31,050[1]	32,085[1]	32,085
British India[11]	29,326	31,688	29,457	31,530	27,280[1]	24,911[1]	26,226[1]	24,870[1]	26,443[1]	25,590[1]	26,443[1]	26,443
Ecuador	25,540	25,495	25,947	27,045	26,962	24,788	27,898	27,490	28,081	26,585	27,382	27,775
Saudi Arabia	72,899	72,899	42,503	59,201	66,604	43,812	82,120	64,531	45,344	48,304	64,785	57,685
Sarawak[12]	14,070[1]	14,539[1]	14,070[1]	14,539[1]	14,539[1]	13,543[1]	14,415[1]	13,920[1]	14,446[1]	13,980[1]	14,446[1]	14,446
Egypt[13]	51,810	60,057	62,150	63,817	62,606	53,534[1]	58,125[1]	57,150[1]	59,272[1]	57,360[1]	59,272[1]	59,272
Italian Empire: Albania[16]	17,100[1]	17,670[1]	17,100[1]	17,670[1]	17,670[1]	16,762[1]	18,415[1]	17,790[1]	18,073[1]	17,790[1]	18,073[1]	18,104
Italy	961[1]	961[1]	930[1]	961[1]	961[1]	899[1]	930[1]	900[1]	930[1]	900[1]	546[B]	546
France	5,760[1]	5,952[1]	5,760[1]	5,952[1]	5,952[1]	5,568[1]	5,952[1]	5,760[1]	5,952[1]	5,760[1]	5,952[1]	5,952
Hungary	8,490[1]	8,773[1]	8,490[1]	8,773[1]	8,773[1]	8,381[1]	9,052[1]	8,760[1]	8,928[1]	8,640[1]	22,063[B]	22,063
Bolivia	960[1]	992[1]	960[1]	992[1]	992[1]	928[1]	992[1]	960[1]	992[1]	960[1]	993[1]	992
Other Countries[17]	7,000	6,975	6,750	6,975	6,975	6,525	7,006	6,780	7,223	6,810	7,223	7,037
WORLD TOTAL	24,201,311	25,543,320	24,496,649	24,959,773	24,579,008	23,456,102	25,634,438	25,101,282	25,792,841	24,758,276	24,870,084	24,309,576

[10] Japanese Saghalin, Taiwan (Formosa) and Hokkaido included with Japan.
[11] Excluding Burma.
[12] Sarawak Oilfields, Ltd., figures.
[A] Estimated Official Sources
[13] Anglo-Egyptian Oilfields, Ltd., figures.
[14] Prussia, Thuringia and Baden.
[15] Formerly known as Austria.
[16] Italian imports of Albanian crude oil.
* Includes all other Netherland India.
[17] Estimate representing Morocco, Cuba, New Zealand, Barbados, Greece, Algeria, Yugoslavia, Australia, Great Britain, Kuweit and China.
[B] Official Figures—Petroleos Mexicanos.

Daily Averages in Metric Tons

	Jan.—August 1940	1939
United States	505,420	453,888
Soviet Union	81,293	81,427
Venezuela	79,985	82,331
Iran	28,518	28,403
Netherland India Sumatra	14,209	14,434
Borneo	4,568	4,780
Java	2,296	2,274
Molucca	257	302
Roumania	17,348	17,135
Mexico	15,696	14,326
Iraq	11,411	11,276
Colombia	10,398	8,301
Trinidad	7,416	7,426
Argentine	8,004	7,157
Peru	4,880	4,927
Bahrein	2,735	2,901
Burma	3,017	2,798
Canada	2,834	2,653
Brunei	2,099	2,104
Great Germany: Old Reich	1,790	1,774
Ostmark	313	301
Slovakia and Moravia	49	49
Poland	1,434	1,432
Japan	1,035	1,037
British India	853	818
Ecuador	888	834
Saudi Arabia	1,939	1,145
Sarawak	466	469
Egypt	1,912	1,727
Italian Empire: Albania	584	570
Italy	28	31
France	192	192
Hungary	396	283
Bolivia	32	33
Other Countries	227	224
WORLD TOTAL	813,531	759,798

Official Crude Oil Production Figures for 1933 to 1939 (Revised) in Metric Tons

	1939	1938	1937	1936	1935	1934	1933
United States	171,053,443	164,346,325	172,822,797	148,707,864	134,912,143	122,913,903	122,601,191
Soviet Union	29,530,168	28,859,000	27,867,025‡	27,384,900	25,241,100	24,092,700	21,330,100
Venezuela	30,533,706	27,845,286	27,733,926	22,945,299	21,990,373	20,112,115	17,293,193
Iran	10,367,112	10,358,495	10,330,480	8,329,289	7,607,500	7,657,970	7,200,093
Netherland India: Sumatra	5,320,320	4,662,836	4,490,137	4,114,710	3,759,006	3,535,035	2,999,352
Borneo	1,680,377	1,719,783	1,739,607	1,773,545	1,815,998	1,924,234	2,013,849
Java	840,950	933,595	960,125	499,097	464,757	510 320	483,331
Molucca	107,047	81,560	72,139	50,446	41,862	36 738	38,300
Roumania	6,228,047	6,603,000	7,153,000	8,704,000	8,394,000	8,473,355	7,387,000
Mexico	5,794,215	5,716,423	6,896,657	6,090,842	5,973,955	5,666,857	5,049,109
Iraq	4,115,845	4,345,000	4,126,185	4,079,066	3,724,231	1,048,108	147,943
Colombia	3,067,568	3,007,935	2,844,251	2,614,092	2,452,635	2,416,432	1,833,606
Trinidad	2,710,515	2,472,943	2,181,676	1,862,796	1,642,446	1,533,122	1,345,532
Argentina	2,651,448	2,432,857	2,330,063	2,202,304	2,036,903	1,997,706	1,950,499
Peru	1,798,557	9,099,885	2,313,691	2,331,454	2,260,903	2,161,990	1,756,867
Bahrein	1,033,472	1,130,734	1,058,557	635,555	173,072	39,008	4,293
Burma	1,087,424	1,039,960	1,083,391	1,047,593	991,456	1,004,951	982,233
Canada	997,391	879,921	378,478	190,495	182,820	178,233	144,686
Brunei	767,700	707,123	576,545	470,991	471,842	386,478	290,808
Great Germany: Old Reich	647,337	552,074	453,451	444,600	427,400	317,500	238,600
Ostmark	109,904	63,468	33,010	7,473	6,616	4,172	360
Slovakia and Moravia	18,103	19,282	18,036	18,665	19,946	25,971	17,776
Poland	522,874	504,678	501,301	510,630	614,760	529,200	550,670
Japan	379,161	356,328	341,040	341,976	326,580	266,520	212,667
British India	322,160	322,125	298,450	273,137	281,072	265,341	224,879
Ecuador	306,824	319,877	306,326	275,293	245,434	231,947	229,578
Saudi Arabia	536,366	66,683	8,070	2,447	Nil	Nil	Nil
Sarawak	171,322	200,126	217,085	221,126	253,799	277,513	315,259
Egypt	657,510	223,058	166,298	177,491	176,436	214,671	232,437
Italian Empire: Albania	208,279	65,313	56,760	32,760	6,152	2,500	1,707
Italy	11,346	13,178	14,000	16,106	15,977	20,180	26,526
France	70,224	72,106	71,008	74,788	74,172	98,025	110,120
Hungary	103,364	42,798	13,910	13	Nil	Nil	Nil
Bolivia	11,904	13,262	15,487	13,197	20,540	19,858	14,085
Other Countries	82,300	34,080	10,000	5,300	4,600	9,100	7,700
WORLD TOTAL	283,844,283	279,111,097	279,482,962	246,449,340	226,610,486	207,971,753	197,034,849

WORLD PETROLEUM ABSTRACTS

Summaries of the Most Important Articles as Published in the Oil Press of the World Dealing With Technical and Economic Aspects of the Petroleum Industry. Edited by Dr. O. W. Willcox

DRILLING

Setting Depths for Casing—Blaine B. Westcott, C. A. Dunlop and E. N. Kemler, before AMERICAN PETROLEUM INSTITUTE, Fort Worth Meeting, May, 1940; 57 pages.

Of the many related problems originating from the drilling of deep high-pressure wells, none has been of greater importance to the successful completion than the casing. Not only does the cost of the casing amount to an important percentage of the total cost of the well, but the operation of the well is dependent upon the successful performance of the casing.

The authors discuss at great length collapse strength in various aspects and outline what they think should be a standard collapse test for casing, standard joint-strength test and bursting strength test.

They make it clear that, from the viewpoint of the user of casing, certain rather fundamental changes are considered to be necessary if safe and profitable production of oil from greater depths is to be possible. The first step in this program involves the use of minimum, rather than average, performance properties of casing. If the minimum values are selected wisely, there will be no danger from failure of the casing under normal conditions. However, if safety cannot be obtained with economy, then profitable operation of deep wells under present restrictions will be impossible. Therefore, it is important that the minimum performance properties be as high as possible.

They recommend that until the API gets around with officially revised specifications, use may be made of temporary minimum performance properties, as follows:

Collapse pressure—75 per cent of the "average collapsing pressures," in *Bulletin 5-C-2;*

Joint strength—85 per cent of the average "ultimate-strength-of-joint" values in *Bulletin 5-C-2;*

Bursting yield strength—87.5 per cent of the values for "internal pressure at minimum yield strength," in *Bulletin 5-C-2.*

Depth Measurements by Means of Multiple-Strand Wire Lines—Henry Emmett Grass and J. P. Hays, before AMERICAN PETROLEUM INSTITUTE, Fort Worth Meeting, May, 1940.

These authors stress the importance of depth measurements especially in delicate thin-pay fields, where operators accustomed to or trained in prolific thick pay fields are likely to be careless with such measurements—carelessness that leads to disastrous results and spoiled wells. They give numerous hints on how accuracy may be achieved, and end their paper with the following observations:

If a depth measurement of a hole is taken both by the sand line and the drilling cable, and the two measurements check within 1 ft. on a 4,000-ft. well, a satisfactory depth of the hole is established.

If both cable and rotary tools are operated jointly on a well, the depth by drill pipe and wire line should check within 1 ft. at 4,000 ft.

In order to assure accuracy in making magnetic surveys, it is suggested that the coring line be "strung" into the well frequently, and checked against drill-pipe measurements.

As the multiple-strand wire lines used in drilling and those used with special measuring devices possess qualities innate to both, depth measurements made by the two methods should check closely.

In the case of special measuring devices, errors inherent in counting mechanisms resulting from inertia slippage and incorrect diameter of measuring sheaves and lines require adjustments to the positive and precise measurements that should be obtained with the drill pipe or cable.

When precise depth measurements are necessary by means of the multiple-strand wire line, it is evident that good workmanship must prevail.

OPERATION

Principles of Oil Reservoir Performance—T. V. Moore, before AMERICAN PETROLEUM INSTITUTE, Fort Worth Meeting, May, 1940.

The author observes that while in some of its branches the production of petroleum has been developed to a high degree of perfection, less progress has been made in that important phase of production dealing with the underground forces which move oil to the wells and which govern the efficiency with which the oil is recovered. However, some of the basic principles have become fairly well fixed; these are restated as follows:

The rate of production should be low enough to permit production by water drive rather than by gas drive.

The velocity of the displacing fluid should be slow enough to permit the capillary and gravitational forces to maintain a substantially uniform rate of displacement through all oil-bearing sands.

When multiple zones of oil-bearing sand are present, the displacement of oil can be carried out most efficiently by producing one zone at a time.

The gas and water must be conserved; and, unless the reservoir contains an ample supply of these fluids to provide for the displacement of all recoverable oil, it may be advisable to return at least a portion of the gas or water produced to the reservoir.

Production operations should be carried on in such a manner as to keep recoverable oil concentrated in as small a part of the sand as possible.

Strategic location of wells, and proper completion and workover of wells and control of production rate, are necessary to the efficient production of oil.

Solving a Well Sanding Problem—Claude Johnston, in OIL WEEKLY, Vol. 98 (1940), No. 3, p. 34.

A well in Louisiana found pay in a sand of exceedingly fine grain, which the conventional screens failed to keep out; the result was that much sand was produced with the oil, with accompanying severe pump rod and tubing wear; often the tubing would clog rapidly and the well would be killed in less than 48 hours following a cleaning out.

After ten settings of screens that failed the eleventh involved the use of a packing of sand between inner and outer shells of specially fabricated screen pipe. Between bottom and top packers approximately 76 feet of this screen was used, set on bottom within the 7-inch casing of the well. This screen pipe was 5½-inch O.D., with accurately spaced and under cut 0.012-inch slots within the entire range. These slots with a maximum width or throat of ⅛-inch, were relieved on the inner side by milling.

Centrally spaced within this outer shell was the tubing extension, of 2½ inch I.D. material. This inner tubing also was slotted, with horizontal slots of the same type as those in the 5½ inch shell, except that the inner slots were 0.008-inch wide. As with the shell, inner milling provided clearance through a portion of the metal of the tubing, and minimized clogging.

Into the space between shell and tubing was poured carefully sized, sharp sand of an average grain size of 0.024-inch, with maxima and minima of 0.029 and 0.021 respectively.

This sand pack, composed of particles too large to enter slots in either shell or tubing formed a uniform screen of the thickness of the annular space over the entire 76 feet of screen, affording adequate channels for oil flow, but arresting the movement of the minute sand particles.

Thereafter to date the well has continued to produce at a satisfactory rate.

Screening Effect of Gravel on Unconsolidated Sands—Ben Gumpertz, in PETROLEUM TECHNOLOGY, May, 1940, Technical Publication No. 1195; 8 pages.

The use of gravel packing has been introduced as a means of keeping sand out of the bottom of the oil well where it would be a great nuisance. The properties of such packing have not heretofore been clearly explained.

Field practice has shown that the screening effect of a given gravel for a given sand apparently varies with the flow velocity. Also, it has been assumed by some operators that the thickness of the walls of the gravel envelope surrounding the well has little effect upon the screening process. It is thought by others that a narrow envelope of gravel might form an ineffective screen.

The author therefore devised an experiment

to determine the effect of gravel-sand size ratio upon screening action under the condition of varying flow velocities and of various thicknesses of the gravel screen. From these experiments he is able to state the following conclusions:

The largest grains of a gravel to be used for screening unconsolidated sand over the entire range of flow velocities should bear a diameter ratio of 11 to the diameter of the sand at the 10 percentile analysis. For velocities below 1.0×10^{-3} ft. per sec. at the well face this ratio can be increased to 16. This in a large measure agrees with the theory and results of Coberly and Wagner.

The minimum width of the walls of a gravel pack, to give good screening action, seems to be that just sufficient to start bridging action. This width may be that of several grains of the gravel.

In a gravel pack there is no relation between flow velocity and gravel-sand size ratio, and the distribution of sand in the pack. Some sand was found to migrate the length of the pack in all cases.

Dehydrating Gas Used for Repressuring the K. M. A. Field—D. H. Stormont in OIL AND GAS JOURNAL, Vol. 39 (1940), No. 4, pp. 34-36.

In repressuring operations in the K. M. A. field in North Texas serious trouble with gas hydrates led to the installation of a large dehydrating plant which is unique in the use of a new combination of dehydrating agents. The combination in question involves the use of propane refrigeration in conjunction with diethylene glycol dehydration. Both of these have been used before but this seems to be the first instance where they have been used together.

The gas (10 million cu. ft. a day) is first compressed in two stages to 300 lbs.; any water precipitated is removed and diethylene glycol is introduced into the gas stream at the approximate rate of three gallons per minute. The glycol-laden wet gas is passed first through a heat exchanger where it is partially cooled by gas exiting from the system. After passing in part through heat economizers the gas arrives in the propane chillers, where the gas temperature is reduced to approximately 0 deg. F.

The propane chillers, which are supplied with propane at the rate of 16,000 lbs. an hour, are of the conventional type. From the chillers the refrigerated wet gas enters a gasoline separator where most of the gaseous fraction separates from the gasoline-glycol mixture; the separation is completed in a series of accumulators and a gravity separator where the diethylene glycol is drawn off for rectification. The dry gas, which now has a satisfactorily low-dew point, is compressed to about 1,800 lbs. and returned to the field for injection into pressure maintenance wells.

In another plant at this field a system comprising an absorption oil tower and an activated alumina drier is also used for dehydrating the gas after de-watering at the first compression stage.

Prevention and Removal of Paraffin Accumulations—W. Y. Brown, before AMERICAN PETROLEUM INSTITUTE, Fort Worth Meeting, May, 1940.

Opinions and facts on the paraffin problem were obtained through a questionnaire sent to producers throughout the industry by the Institute's Eastern District Topical Committee on Production Practice. From the answers received the following conclusions seem warranted.

The problem today is about equal in severity to that experienced by operators 10 years ago. Although conservation policies have tended toward alleviation, the production-rate limitations have aggravated paraffin deposition. This is particularly true in young fields where production is obtained by natural flow.

Other than a widespread adoption of those principles promoting gas conservation and increased ultimate recovery, nothing of note has been applied successfully during the past decade for preventing paraffin accumulations.

Some progress has been made, however, in the direction of removing the accumulation after it has occurred.

Although the primary factor influencing the preference of any paraffin-removal method is cost, no single technique for handling a given type of deposition can be recommended universally.

A general decline, and in the newer fields complete disappearance, of the use of steam as a paraffin-removal technique is observed. This decline is a result of the replacement of steam by other means as pumping power.

Those methods now preferred by oil producers for removing paraffin accumulations as indicated by the Institute's questionnaire are listed hereinafter in the order of their popularity. Such methods as pertain only to strongly specialized equipment are not included.

A. From Tubing of Flowing Wells:
   1. Use of wire-line scraping tools.
   2. Use of automatic scrapers or darts.
   3. Stopcock flowing or purging.

B. From Tubing of Pumping Wells:
   1. Pull rods.
   2. Use of commercial solvents and softeners.
   3. Pull tubing, and steam same.

C. From Flow Lines:
   1. Burn crude oil in bell holes under lines.
   2. Purge lines by opening chokes of flowing wells.
   3. Flush lines with steam.
   4. Circulate hot water, kerosene, or gasoline through lines.

D. From Stock Tanks:
   1. Clean tanks, disposing of sediments by spreading on lease roads or burning in pits.
   2. Reclaim through heating plants.

E. From Sand Face or Liner Section:
   1. Batch treatments of heat-generating chemicals, commercial solvents or softeners, hot water or gasoline.
   2. Use of steam.

Paraffin Removal by Electrical Process—B. Mills, in OIL WEEKLY, Vol. 98 (1940), No. 2, pp. 15-17.

Thirty wells in the Texas Panhandle that had been giving paraffin trouble were equipped by Drilling and Exploration Co. with facilities for melting the paraffin deposits by electrically generated heat. In this method the hanger is insulated from the casinghead by an insulated medium shaped to fit the heads, while the tubing is insulated from the casing by conical-shaped insulators placed around the couplings to hold the tubing in spaced relation to the casing. A spring contact is set at the required depth to complete the circuit between the tubing and casing. A direct or alternating current of high amperage and comparatively low voltage is then introduced by connecting the input terminal to the tubing and the return terminal to the casing. This removes the necessity for using cables between the tubing and casing, since the current passes down through the tubing, through the contact springs, and back through the casing or formation. Heat is generated in the tubing, rather than in the casing because of the smaller diameter of the tubing and its consequent greater resistance to the current.

Usually the electrical connections are not installed until mechanical failure or paraffin trouble makes a pulling job necessary. When the casing and tubing are replaced the joints are carefully cleaned and made up tight. The current for heating is supplied by a variably controlled D. C. generating unit driven by a 150 h. p. gasoline engine mounted on a truck; the amperage is around 675-775 with a voltage of 79 to 88. The highest temperature that has been so far required is 109 deg. F. and the time required is about one hour. After melting, the parffin need not be pumped out immediately as it shows a tendency to remain some time in solution in the oil.

The system has been in operation for a period of two years and has given satisfactory results. Total oil production from the 30 wells has been about 115,000 bbl. and the calculated cost of the paraffin treatment has been $787.50.

NATURAL GAS

Experiment with Liquefied Natural Gas for Storage—W. V. Howard, in OIL AND GAS JOURNAL, Vol. 38 (1940), No. 52, pp. 18-19.

Reference is made to an experimental plant where natural gas is liquefied and stored in cork-insulated tanks at a pressure of 5 to 10 lbs. and a temperature of −250 deg. F., after first being deprived of all traces of water, CO_2 and SO_2. The storage tanks are made of 2 percent nickel steel. The insulation seems to be very effective, as only 1 percent of the liquefied gas is vaporized in 24 hours, and it is thought that this might be reduced to ¼ of 1 percent by laying on another 8 inches of cork insulation. At the present time liquefied gas at this plant is being vaporized and turned into the lines at the rate of 500,000 cu. ft. per day.

The practical value of this experimental work lies in the possibility of storing gas in liquid form during slack periods so as to provide for peak loads without the necessity of providing enlarged transmission and producing capacities to allow for these peaks. Another important factor is the reduction in cost of storage facilities, as 1 cu. ft. of liquid natural gas is equivalent to 600 feet in the gaseous state. No cost details are given.

Experience with Underground Storage of Gas—F. H. Finn, before AMERICAN GAS ASSOCIATION, Houston, May, 1940.

As a result of the experience of the Peoples' Natural Gas Co. and the New York State Natural Gas Corp., it has been found that the most effective storage for all practical purposes is in small pools where large open-flow wells are available, thus resulting in high capacity to produce for a relatively small amount of gas stored. It is also considered important that the storage take place under conditions whereby the gas is pumped only one way, i.e., either pumped into storage or pumped out of storage. Pumping of the gas both ways increases the expense considerably.

Storage has been found to be an excellent solution for the problem of peak loads, as the storage process can be accomplished at times when gas is not needed so badly for the market, and withdrawal can be made at a rapid rate when market requirements are excessive.

It is believed that the most economical type of storage is that which can be made in pools which will hold from 500,000,000 to 3,000,000,000

cu. ft. of gas at a rock pressure of not more than 500 lb., and from which the gas can be withdrawn at a rate which will accomplish complete emptying of the storage in 6-month time if it is needed.

Methane as Fuel for Diesel Tractors, Anon, Revista Italiana Petrolio, 1940, April, pp. 15, 17, 18.

A report is made of the use of compressed methane (natural gas) as a fuel in Diesel engines in place of heavy naphthas. The subject is of some importance in a country like Italy which must import liquid hydrocarbons, but has a considerable native supply of natural gas which is available in high pressure drums at filling stations along many of the principal roads in the northern part of the country.

The experiments, which were made on the engine bank and on the road, showed that the only alterations necessary were to change the compression ratio to about 1:11 and install a set of spark plugs, and to make a few minor adjustments that would not interfere greatly with the later return of the engine to normal Diesel service. Thus equipped and supplied with compressed methane the Diesels gave an increase of 45 to 50 percent in brake horse-power as compared to what they delivered when working on naphtha.

PIPELINES

Pyralin Coatings for Pipe Lines. D. H. Johnson, in PIPE LINE NEWS, Vol. 12 (1940), No. 7, pp. 8-9, 16.

Under the title "Bodyguard for black gold" an account is given of experiments in protecting underground pipes with pyralin sheets (a nitrocellulose product). Experiments with this material date back to 1934 in the Texas oilfields, and it seems that it answers the purpose. The recommended grade is a black pyralin that comes in sheets 0.01 inch thick which are wrapped spirally around the pipe and the laps cemented water-tight with a special cement. No cost information is given.

Selection of the Most Economical Pipe and Valve Size and Rate of Flow in Piping Systems—S. P. Johnson and F. L. Maker, before AMERICAN PETROLEUM INSTITUTE, Fort Worth Meeting, May, 1940.

The size of long pipe lines usually is determined by balancing pipe cost against pumping cost. As a formal economic study for each element of a plant piping system would be out of the question, various shortcut methods commonly are employed, the most usual being to assume a reasonable velocity or a reasonable pressure drop on the basis of experience or common sense. This paper examines these methods, and shows that they are apt to err when the density or viscosity of the fluid is unusual or when special materials are required. A rational method of selecting pipe size for any fluid is worked out, and charts are included which permit the economic selection of size to be made with a minimum of calculation.

It is shown that valves, and sometimes other appurtenances, are not necessarily best made the same size as the line. The economy of small-size valves has been worked out, and suggestions are made for installation.

The flow rate in a piping system usually is dictated by process requirements or basic assumptions. There are, however, interesting exceptions when the designer of the piping must choose the flow rate as well as the pipe size to secure the lowest overall cost. One of the most important problems of this class arises in designing a loading system for tank ships, tank cars, or trucks when a three-way balance should be struck between pipe cost, pumping cost, and cost of delay. This problem is simplified by the development of a chart showing the most economical flow rate for any given or assumed loading system.

Microbiological Anaerobic Corrosion (of pipe lines). Raymond Hadley, before AMERICAN GAS ASSOCIATION, Houston, May, 1940.

The author directs attention to a form of corrosion that occurs only under anaerobic soil conditions, but which is quite important under circumstances favorable to it. In fact, it is said to be astonishingly common in certain eastern states.

One of the components of the products of anaerobic corrosion is ferrous sulphide, which is produced by the metabolic activity of bacteria which are able to reduce sulphates, from which they liberate hydrogen sulphide which then attacks iron and steel; the presence of ferrous sulphide on a buried pipeline can be taken as an indication of bacterial corrosion.

This bacterial corrosion appears to be more virulent than corrosion which occurs under aerobic conditions. This is indicated by the fact that the depths of the pits on the steel surface are deeper than those which occur in adjacent areas where conditions are not favorable for anaerobic bacteria. Hence the sulphate reducing bacteria constitute more of a hazard to the pipe line.

Another characteristic of the microbiologic anaerobic corrosion process is that it is not "self stifling". The rate of corrosion, or the rate at which the pits increase with depth, instead of decreasing with time as is otherwise the case, seems rather to accelerate with the passage of time, at least as regards some localities.

The author notes that the study of this form of corrosion has been neglected, and that methods of combating it economically have not been much investigated.

PHYSICS

Physical Constants of Asphaltic Bitumens R. N. J. Saal, K. Meinema and P. C. Blokker, in JOURNAL INSTITUTE PETROLEUM, Vol. 26 (1940), No. 199, pp. 246-255.

This paper gives a survey of the following electrical properties of asphaltic bitumens: dielectric strength, angle of dielectric loss, dielectric constant and electrical conductivity; a description of the methods by which these constants are determined is also given.

The dielectric strength, dielectric loss, and dielectric constant of asphaltic bitumens are of great importance for the different applications of bitumen in the electrical industry, where it is used for instance in pothead compounds, sealing compounds for transformers, impregnation material for condensers, insulation material for cables, etc.

The dielectric strength of a material is the minimum value of the electric field intensity at which a disruptive discharge occurs in the material under specified conditions.

Among the bitumens tested a Venezuelan steam reduced bitumen having a penetration of 180 and a softening point of 39½ deg. C. showed a dielectric strength of 10; a similar material with penetration 11 and softening point 83 deg. had a dielectric strength of more than 60; evidently this property is closely related to the hardness of the material.

When an insulating material is exposed to an alternating electric field, so-called dielectric losses usually occur, which manifest themselves as heat evolution. These losses play an important part in insulation technique, for instance, when a current is sent through a cable; this involves loss of electrical energy, while, moreover, the condition of the cable may be adversely affected by the generated heat.

Among the bitumens examined none showed a loss of more than one watt at 70 deg. C.; losses are therefore negligible with alternating voltage of low frequency; at higher frequencies the losses may be larger. The dielectric contant lies between 2.5 and 3.3 with bitumen from cracked residue showing the higher value.

The specific conductance increases considerably with rising temperature and is generally the higher the softer the bitumen; it is approximately proportional to the square of the penetration at a definite temperature.

Steady Flow of Gas-Oil-Water Mixtures through Unconsolidated Sands — M. C. Leverett and W. B. Lewis, in PETROLEUM TECHNOLOGY, Vol. 3 (1940), No. 2, Technical Publication No. 1206; 9 pages.

Since three phases—oil, gas and water are known to be present in oil reservoirs it is essential to know the effective permeabilities to the several fluid phases and the relationship between the composition of the pore space and that of the flowing stream in order to handle satisfactorily certain problems of oil production.

As a contribution to this subject the authors made an experimental study of various mixtures of the three phases that flowed through several sands, and from the results they deduce the following conclusions:

The relative permeability to water is determined by the water saturation alone, and is not affected by the introduction of an additional nonaqueous phase.

The relative permeability to gas in three-phase flow is slightly less than would correspond to the same gas saturation in two-phase flow.

The relative permeability to oil varies in a more complex manner, being in some regions less and in others more than for the same oil saturations in two-phase flow.

The isoperms for all components are independent of the viscosity of the oil phase. Points determined using kerosene and points using the more viscous blended oil fall along the same isoperms.

The presence of appreciable amounts of all three phases in a flowing stream in equilibrium with the fluid in the pore space is limited to a relatively small region of pore composition.

CHEMISTRY

Colloid Chemistry of Clay Drilling Fluids. —A. G. Loomis, T. F. Ford and J. F. Fidiam, in PETROLEUM TECHNOLOGY, Vol. 3 (1940), No. 2, Technical Publication No. 1201; 12 pages.

It is held that solutions to outstanding problems in the further development of drilling muds are to be sought largely in the light of the colloid chemistry of clay suspensions as it has now been

developed. Prominent in a study of these problems will be an explanation of the effect of the various chemicals now in use to control the rheological properties of drilling muds.

It is shown that viscosity-reducing chemicals are absorbed on specific surfaces of the clay particles and that they reduce the viscosity of suspensions by destroying the portion of the absolute gel strength that is attributable to adhesion between particles. On the other hand, salts are not adsorbed but cause gelation and coagulation because of induced changes in the interparticle ionic atmospheres.

Results of a comparison of the viscosity-reducing effects of the polyphosphates with other standard viscosity reducers show that sodium pyrophosphate is one of the most effective. However, it is found that among the polyphosphates the pyrophosphate, which has the lowest molecular weight, produces the least permanent effect and that as the molecular weight increases to the decaphosphate there is a corresponding increase in the permanence of the viscosity lowering. This behavior suggests diffusion into inner particle surfaces, the rate of which decreases as the size of the adsorbed molecules is increased.

Proof is given that the tannate and pyrophosphate ions are adsorbed on the same surfaces of the clay particles and that the polyphosphates produce equal viscosity-lowering effects per molecule because they cover equal areas per molecule.

The application of thixotropy and gel strength to drilling problems is discussed in detail and it is shown that while both elasticity and mechanical strength of clay gels are destroyed as a result of chemical treatment, the initial gelling rate of muds in the completely de-gelled condition is not significantly changed. An equivalent degree of gel strength, which may differ in its mechanism but not in its utility, may be regained in a treated mud by adding salt.

On the basis of the detailed structure of clays as revealed by X-ray analysis, chemical formulas are written for colloidal clay particles and utilized to explain most of the phenomena shown by clay suspensions.

REFINING

Reducing the Time of Regenerating Doctor Solution. Anon. REFINER, Vol. 14 (1940), pp. 123-124.

The old system used at the plant of the Leonard Refineries (Alma, Mich.) required 24 hours or longer to regenerate the spent doctor solution; in this old system the regeneration was effected in open steel vats equipped with steam heating coils and spiders for blowing and mixing with compressed air.

It turned out that the unsatisfactory performance of this system lay in failure to obtain maximum intimacy of contact between the air and the doctor solution. The system was therefore substituted by the following arrangement: A vertical column, consisting of a 6-inch pipe 12 feet long was erected at the side of the treating vat; 13 alternate slots were cut in this pipe into which baffles were slipped and welded in place, thus providing conditions for high turbulence. The bottom of the tower is connected with the bottom of the vat, the pump and a line for compressed air; the air and the 20 bbl. batch of spent doctor rise through the column, from the top of which the solution falls back into the vat. Proper temperature conditions are maintained in the circulating fluid.

The saving in time and steam by reducing the duration of the operation from 24 down to two hours quickly absorb the cost of this simple apparatus.

Lime Wash for Hydrogen Sulphide Removal. Anon. REFINER, Vol. 19 (1940), No. 4, pp. 121-122.

The Big Spring (Tex.) refinery of the Cosden Petroleum Corp. which processes 17,000 bbl. of West Texas crude a day and has a cracked distillate output of 8,000 bbl., uses a lime wash made from hydrated lime as a first stage in the treatment of its 400-end point stabilized gasoline. The function of the lime wash is to remove sulphur that is present in the form of hydrogen sulphide. The object of this step is to reduce the expense of the sweetening operations as usually conducted.

The complete process as here conducted consists of making a thin suspension of the hydrated lime in water, which is circulated through the gasoline-treating units until it is exhausted, or spent, after which it is dumped into the sewer. The thoroughness of the treatment is controlled by a lead acetate test, which has consistently indicated that the gasoline that comes from the lime treatment is free from hydrogen sulphide. The next step is a thorough wash with a 20 deg. Be. caustic soda for removal of a portion (25 percent) of the mercaptans before finishing. The caustic used for mercaptan removal is regenerated. The gasoline from the caustic treatment goes directly to the doctor-treating system; the lead sulphide in the doctor solution is recovered and used after the material is passed through a centrifugal for reclaiming hydrocarbons entrained in the emulsion.

The reduction in treating cost after installation of the revamped treating system is quite an item. The NaOH requirement for treating an average of 8,000 barrels of cracked gasoline per day is only 35,000 pounds per month. This amount is less than .13 pounds per barrel of distillate treated, which, when reduced to requirements is only about .00308 pounds per gallon of distillate. The lead for doctor treating is about 1,200 pounds monthly, which is only about .0000105 pounds per gallon, showing an extremely high recovery of lead from the treating solution, and a surprising low cost per barrel.

GENERAL

Cooperative Fuel Research Motor-Gasoline Survey, Winter 1939-40—E. C. Lane in BUREAU OF MINES REPORT OF INVESTIGATIONS, No. 3524 (June, 1940).

This is the ninth in a series of reports on properties of commercial motor fuels made in accordance with a cooperative agreement between the C. F. R. committee and the Bureau of Mines. The present report presents analytical data for 2,033 samples, representing the products of approximately 80 companies, which, as in previous surveys, include both large and small suppliers. As in previous surveys, the data are divided into the three groups of samples of regular-price, premium-price, and third-grade gasolines, and each group has been averaged separately.

For the country as a whole the grand average octane numbers (A. S. T. M.) for the three principal grades of gasoline came out as follows:

Regular-price gasoline	72.7
Premium-price gasoline	78.5
Third-grade gasoline	64.2

A comparison of data for the winter of 1939-40 and that of 1938-39, respectively, for the three grades of gasoline, shows that the spread of the octane number for 90 percent of the items in the regular-price grade for 1939-40 is greater by 2.2 numbers than for 1938-39, the low limit of the range being 1.1 and the high limit 3.3 numbers above those of the previous year; in the premium-price grade, both the low and high limits of 90 percent of the items are slightly higher than in 1938-39, but the spread between them is slightly less; in the third grade the low limit of 90 percent of the items is about 2 octane numbers higher, and the high limit 3 octane numbers higher, giving a spread 1 number greater than in 1938-39.

The limits of the ranges of vapor pressures in which 90 percent of the items of regular-price, premium-price, and third-grade gasolines is included, are approximately the same as for the corresponding groups during the winter of 1938-39, although the spread for the third-grade gasolines is slightly wider than for the previous winter. The limits of the temperature ranges in the distillation for the regular- and premium price gasolines are very much like those of the previous winter, although the spread is slightly less. The third-grade gasolines have a slightly narrower spread than for the previous winter, and the limits of the range are slightly lower.

Prospects of Diesel-Engined Air Craft. Oscar Tokayer, in PETROLEUM PRESS SERVICE, Vol. 7 (1940), No. 3, pp. 267-268.

Previous knowledge and experience has not yet overcome the difficulty of developing a Diesel aero engine which, weight for weight, can approach, at cruising speed, the horse-power of a modern 100-octane gasoline aviation engine. Moreover, the Diesel engine suffers from the inherent disability of being unable to run satisfactorily at heavy overload; it lacks the capacity to supply that extra effort necessary to get a laden aircraft off the ground; and until ways and means of circumventing this inherent drawback are devised, the Diesel-engined machine must necessarily carry a lighter commercial load.

Thus even on paper Diesel transport can only begin to compete with the gasoline-engined aeroplane over distances equivalent to 7½ hours or more of continuous flying; for it is only at this point that the saving in weight due to a lower fuel consumption can overcome the initial payload deficiency.

The practicability of refuelling an aircraft in the air from a tanker machine, demonstrated in 1939, has removed one of the outstanding theoretical objections against the Diesel aircraft, for—again on paper—there appears to be no reason why a Diesel-engined aeroplane should not take off with a small quantity of fuel and a full commercial load, subsequently having its tanks "topped up" in the air.

Outstanding among the advantages of the Diesel-engined aircraft is the reduced danger of fire, since gas oil is naturally far less inflammable than gasoline. This factor, however, is probably of psychological rather than material importance. The use of the Diesel also removes radio interference problems. These points are particularly attractive for training machines; and in view of the relatively small size of engine required it is here that the aircraft Diesel can best find its opening.

It is sometimes claimed that Diesel aircraft fuel would be cheaper than aviation gasoline; but

this appears doubtful. The number of crudes capable of yielding a raw gas oil distillate from which an aviation Diesel fuel might be made is, in fact, limited; in every case solvent extraction (as used in high grade lubricating oil manufacture) and the incorporation of "dopes" to improve ignition quality, would be required—and both these are expensive.

To date, practically the only development work on the aviation Diesel engine has been done in Germany. But since a number of heavy Diesel-engined Junkers transport machines were put into service in 1934, little practical progress has been made. This, however, has been entirely due to the intense pre-occupation of the engine manufacturers with military design. Three or four years are generally required to develop a new aircraft engine from experimental embryo to the finished article, and the German manufacturer has recently been allowed little time to devote to this branch of research.

To sum up, it may be said that for long range and high altitude flying, the Diesel engine has little promise of success at present, but that the lessened fire risk might make further research into the small Diesel-engine for primary trainers well worth while.

Calcining Petroleum Coke in California. L. P. Stockman, in OIL AND GAS JOURNAL, Vol. 39 (1940), No. 8, pp. 36; 38.

Petroleum coke from refinery cracking units, though an excellent domestic fuel, is virtually a drug on the market in California due to the relatively low consumer price of natural gas.

Lately it has appeared that an unsatisfied good market exists for a high grade pure carbon. Petroleum coke as it comes from the cracking coking units is not pure carbon, as it contains around 15 percent of volatile matter, whereas a high-grade carbon should contain less than one percent of such impurities.

The principal uses for high-grade carbon are in the manufacture of carbon electrodes and anodes in dry-cell batteries and for general metallurgical lines where a pure quality of carbon is required. This carbon is also used in the aluminum industry, for manufacture of carbon brushes for electric motors, for abrasives and other miscellaneous uses. It is sold to metallurgical consumers throughout the world under very rigid specifications and analytical guarantees.

To produce a carbon of the required quality a plant has been erected in California to treat about 384 tons of petroleum coke a day, from which it is expected to produce 323 tons of pure amorphous carbon a day. The process consists of two-stage heating the coke in calcining chambers to a temperature of approximately 2,700 deg. F.; the necessary heat is supplied by a fuel-oil fired furnace. The same company is now operating two similar plants in Illinois and Texas.

Wildcat Drilling in 1939—Frederic H. Lahee, in BULLETIN ASSOCIATION PETROLEUM GEOLOGISTS Vol. 24 (1940), No. 6, pp. 953-958.

This fifth consecutive annual review of wildcat drilling in the United States lists a total of 8,624,602 feet drilled in 2,589 holes, of which 270 of the holes were producers with a total depth of 1,109,687 feet, and 2,319 were dry holes with a total drilled footage of 7,514,915 feet. The distribution of these holes is given by states in the accompanying table.

From these figures it may be calculated that only 10.43 percent of the holes drilled and 12.87 percent of the footage was successful.

As regards the methods used for locating the sites for these holes the information obtained indicated 217 wildcats that were drilled on technical advice based on geology and/or geophysics were successful (oil or gas) and 1,446 were dry; 43 holes located for a variety of assigned non-technical reasons were successful and 666 were dry; 10 producers and 207 dry holes were located for reasons unknown; thus 13 percent of holes located by technical advice were successful as compared with 6 percent located without scientific help. A reference to previous years shows that locations based on technical recommendation continue to be about twice or three times as successful as "hunch" wildcatting.

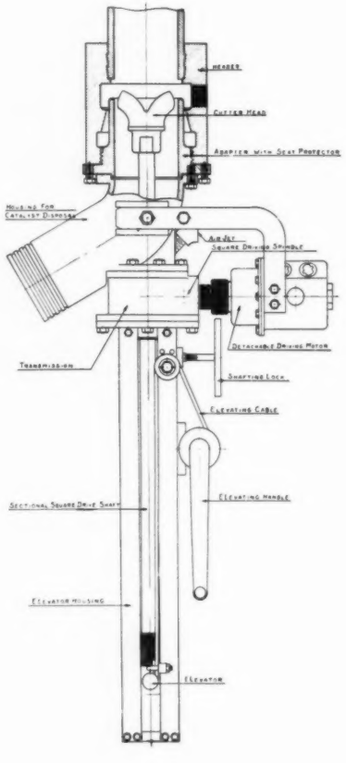
The tendency of late years is for the average depth of wildcat holes to decrease. This is explained by the great increase of wildcat drilling in the shallow fields of Illinois, Indiana and Michigan.

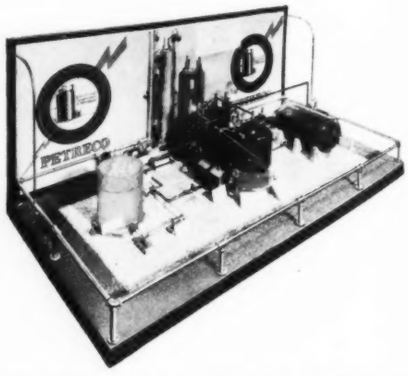
Number of Oil Wells, and Dry Holes Drilled as Wildcats in 1939

States	Oil		Gas		Dry		Total Number of Holes	Total Footage Drilled
	Number of Holes	Footage Drilled	Number of Holes	Footage Drilled	Number of Holes	Footage Drilled		
Alabama					6	20,579	6	20,579
Arkansas	5	36,119	1	1,618	33	114,529	41	152,266
California	4	33,049			98	434,679	102	467,728
Colorado					6	35,614	6	35,614
Florida					2	10,208	1	10,208
Georgia					3	7,154	3	7,154
Illinois	29	70,986	1	2,992	448	962,133	478	1,036,111
Indiana	17	47,822	3	2,124	83	172,053	103	221,999
Kansas	19	63,017	2	4,242	74	258,031	95	325,290
Louisiana	8	84,402	7	50,347	125	862,821	140	997,570
Michigan	12	19,521	1	2,035	361	668,145	374	689,691
Mississippi	2	10,172			16	67,195	18	77,867
Missouri					22	37,680	22	37,680
Montana					6	10,245	6	10,245
Nebraska	1	2,292			6	14,001	7	16,293
New Mexico	6	13,897			19	62,856	25	76,753
Oklahoma	17	64,386	4	17,886	91	388,470	112	470,742
So. Carolina					2	2,815	2	2,815
So. Dakota					1	6,188	2	6,188
Texas	104	467,277	27	115,013	906	3,353,512	1,036	3,935,802
Wyoming					8	26,007	8	26,007
	224	913,440	46	196,247	2,319	7,514,915	2,589	8,624,602

CORRECTION

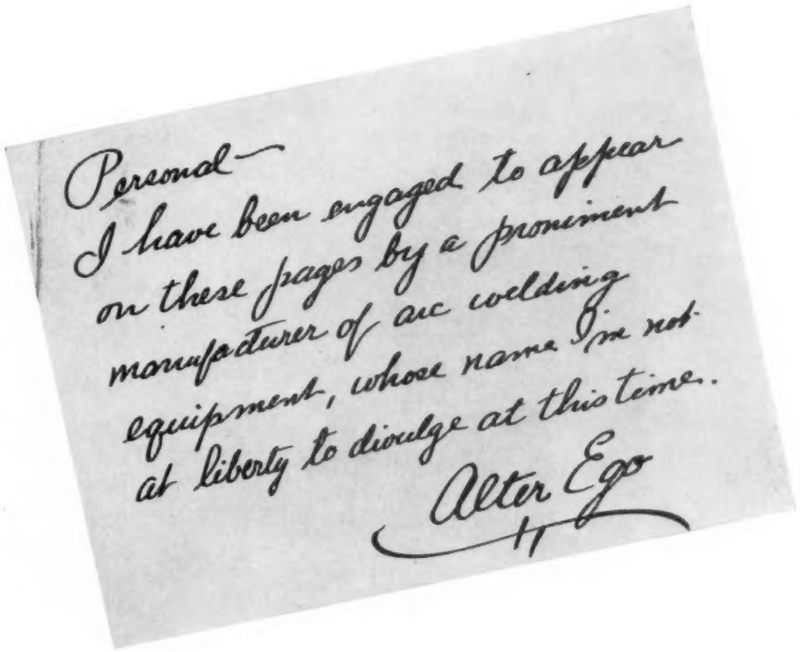
The editors regret that through an error in the August issue the illustration of the minature Petreco Electromatic desalting plant (below) appeared with a caption written for Airetool Manufacturing Company's recently developed catalyst tube cleaner. Both illustrations are here reproduced with correct captions.





Illustrated above is a minature Petreco Electromatic plant which was designed to show the operation of this unit in relation to a refinery but which actually de-salts almost a gallon a minute. Built on an exact scale of ½ in. to one foot, it represents a plant having a capacity of 4,000 bbl. daily and forms part of a valuable educational exhibit.

Illustrated on the left is a recent development announced by the Airetool Manufacturing Co. which has decreased tube cleaning time 75 percent and labor costs 50 percent in a test demonstration. It is said to have removed much of the danger in cleaning reactor tubes in polymerization units.


Personal—
I have been engaged to appear
on these pages by a prominent
manufacturer of arc welding
equipment, whose name I'm not
at liberty to divulge at this time.
Alter Ego

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KIRKEBY HOTELS

Federal Oil Control

(Continued from page 29)

In the trial in the District court the defendants, in addition to citing economic factors, including control of production, the Connally Act and increase in consumptive demand, as responsible for prices rises and spot markets' stability in 1935 and 1936, advanced government approval of the program as ground for exemption from the prohibitions of the Sherman law. This contention the trial judge disallowed in his charge to the jury and the Circuit Court of Appeals held this charge reversible error, since it was based upon the theory that such a combination was illegal *per se*. In the view of the Circuit Court the activities were not illegal unless they constituted an unreasonable restraint of trade. Hence, since this issue had not been submitted to the jury the Court reversed the findings and remanded the case for new trial so that "the character of those activities and their effect on competition could be determined."

In the dissenting opinion Supreme Court Justice Roberts summarized the case and his reasons for finding error in the judgment of the trial courts as follows:

> "There was substantial evidence that all the defendants agreed to, or did, was to act in concert to eliminate distress gasoline; that such gasoline was a competitive evil in that it tended to impair or destroy normal competition. There was substantial evidence what they agreed to, and did, neither fixed nor controlled prices nor unreasonably affected normal competition and that their conduct affected prices only in the sense that the purchase of distress gasoline at going prices permitted prices to rise to a normal competitive level. There was no evidence that, as charged in the indictment, they agreed to, or in fact did, fix prices. The Court of Appeals, as I think, correctly held 'that the substance of what was accomplished and agreed on was that the major companies would purchase from the independent refiners the latter's surplus gasoline at going market prices'."

No sooner was this case completed than the Department of Justice, with the approval of the Administration, launched further investigations which were intended to result in an even more sweeping prosecution based on the threat to destroy the integrated form of organization to which the oil industry owes much of its present efficiency.

Before these later moves by the Justice Department had taken form President Roosevelt, acting on the recommendations of the Energy Resources unit of the National Resources Board, sent a letter to the House Interstate Commerce Committee accompanied by a draft bill providing for federal regulation of the production of oil and gas and their transportation in interstate commerce.

The measure was introduced by Representative Cole August 5, 1939 and since that date has constituted the major legislative proposal dealing with petroleum pending in Congress. After exhaustive hearings by the Cole subcommittee lasting through March of this year no conclusion has been reached regarding the legislation. In presenting the bill Representative Cole emphasized that it had "not been prepared by me or any member of the subcommittee over which I presided as chairman in 1934 and which has handled all legislation on the subject of petroleum since that time."

The bill would establish an Office of Petroleum Conservation in the Department of the Interior under the direction of a Commissioner of Petroleum Conservation who would be authorized to determine what constitutes waste in the production of crude oil and natural gas. He would be empowered to prevent any "wasteful" production. The measure sets forth a long list of production practices designated as wasteful but in the end invests the Commissioner with additional discretion to make other findings as to waste.

There also would be established a Council on Petroleum Conservation consisting of

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eighteen members, to be appointed by the Secretary of the Interior. Nine of the members would be state officials charged with the administration of petroleum conservation laws, six would be persons engaged in the production of petroleum and three would be teachers of subjects relating to petroleum. The Council would meet annually to confer with representatives of the federal government on matters laid before the meeting and relating to waste in production and civilian and military needs. The Council also would arrange for a current interchange of information with the office of Petroleum Conservation on production methods and practices.

Taking into account the detailed standards outlined, the commissioner would be required to regard as *prima facie* evidence of avoidable waste any operation substantially at open-flow capacity.

State officials and operating companies would be notified of the findings and the regulations and the opportunity would be given to make corrections. If the corrective measures are not applied the commissioner is authorized to bring action in the United States district court to enjoin such practices.

The bill also provides the commissioner with authority to approve voluntary agreements to eliminate avoidable waste among the operators in any single oilfield. Likewise he is further authorized to cooperate with states or agencies acting pursuant to agreements between two or more states and with educational and research organizations, public or private.

Pertinent oil activities in federal government would be consolidated in the Office of Petroleum Conservation and the Connally Act made permanent. The agencies listed for consolidation include the present Petroleum Conservation Division, Bureau of Mines, Geological Survey, Office of Indian Affairs, General Land Office in connection with oil and gas leased on public, Indian and naval reserve lands. In the aggregate these agencies expend approximately $1,400,000 and have nearly 450 employees in Washington and the field. This provision will be recognized as the outgrowth of the earlier battle betwen Secretary Ickes and the Department of Commerce for control of all agencies dealing with oil under a proposed Department of Conservation.

Although Representative Cole had been informed that the bill was designed "solely as an oil conservation measure" and does not attempt "to control supply through the establishment of production, marketing or transportation quotas; does not affect imports or exports nor provide for any coordinated industrial action in refining and marketing," the hearings developed acknowledgment that, in any "conflict of authority" it is the "purpose of the measure to make federal authority prevail". The admission was made by Secretary of the Interior Ickes at the closing session of the hearings which had been held in both Washington and New Orleans to disclose major opposition to such federal control.

In answer to a letter from Representative Cole in which he noted the "essential ob-

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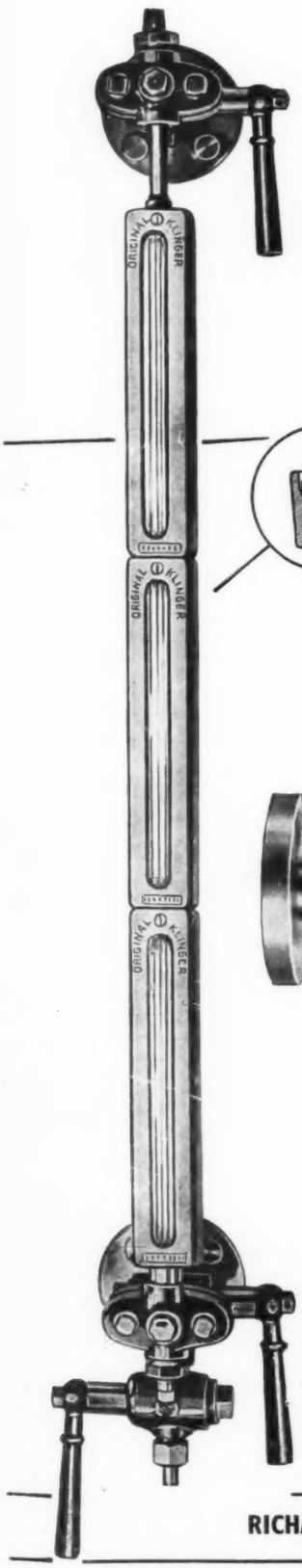

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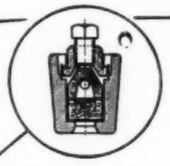

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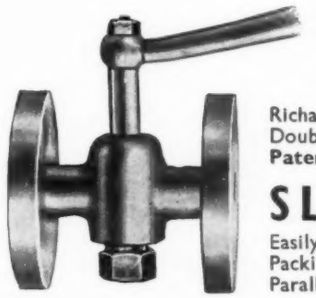

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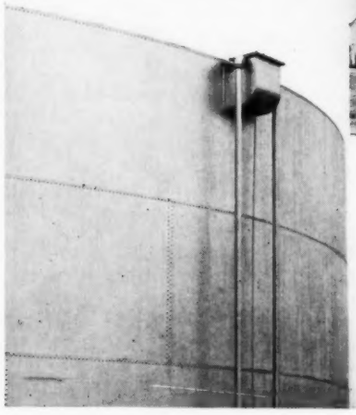

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jections" to the measure presented by state officials and representatives of the industry at the hearings President Roosevelt replied that instead of a different legislative approach to the problem than embodied in the bill the modification should be in enforcement procedures.

In this letter the President said:

> As I understand the controversy over H. R. 7373, there is little objection to the federal government prescribing, in order to conserve our petroleum resources, standards of production to which oil producers should conform as a condition to the shipment of their oil in interstate commerce. The principal objection to the proposed legislation seems to be that it provides for federal enforcement of such standards.
>
> This being the case, I should think it would be possible to agree that the standards of production necessary to qualify oil for shipment in interstate commerce should be prescribed by federal government but that these standards should be enforced by the federal government only if an authorized federal agency finds that the states have failed to enact laws requiring conformity with federally prescribed standards or have failed persistently to enforce compliance with such standards when required by state laws. In so far as the states fail to enact or enforce oil and gas conservation laws requiring conformity with the standards prescribed by federal law I should think that oil producers should be given the right to qualify their oil for shipment in interstate commerce by entering into voluntary agreements, subject to the approval of the authorized federal agency, to conform with such standards. Legislation along these lines would in effect be an extension of the principles of the act of February 22, 1935, generally known as the Connally Law.

These words of the President clarify the purposes of a policy that included such divergent aims as were embodied in the NRA and the Madison trials. If the industry accepts federal control, the President expresses the opinion that: " . . . the oil producers should be given the right to qualify their oil for shipment in interstate commerce by entering into voluntary agreements, subject to the approval of the authorized federal agency . . "

Under presidential proclamation, dated July 26, the President, acting under provisions of Section 6 of the Act of Congress approved July 2 extended export license control to aviation motor fuel, aviation lubricating oil and tetraethyl lead and embargoed shipments to all countries except those in the Western Hemisphere.

Another punitive measure prepared for the oil industry if it continues recalcitrant in regard to federal control is the Treasury Department's proposal to amend the percentage depletion allowance provision of the income tax law to abolish the 27½ percent depletion allowance and substitute for it the former cost allowance. This proposal failed to secure the approval of the House Ways and Means Committee, so the Treasury Department announced that it would press for adoption of the proposal as an amendment to the excess profits tax on the floor of House or Senate. It has been estimated that such a change in the depletion allowance would cost the industry some $80,000,000 annually.

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Annual Refinery Issue
1940

Photograph by Robert Yarnall Richie

A LITTLE over thirty years ago there were but a few thousand miles of R.F.D. service in the entire country. Today, there are 1,380,000 miles. By automobile the average carrier covers a route in three and a half hours that took the postman of thirty years ago, ten hours with horses and wagon. With the automobile lessening time to do many things, came a new Industry—Natural Gasoline. The first Hanlon plant built in 1908 had only a few barrels capacity—today Hanlon-Buchanan plants with thousands of barrels daily capacity, supply domestic, coastwise and foreign markets with uniform high quality Stabilized Natural Gasoline.

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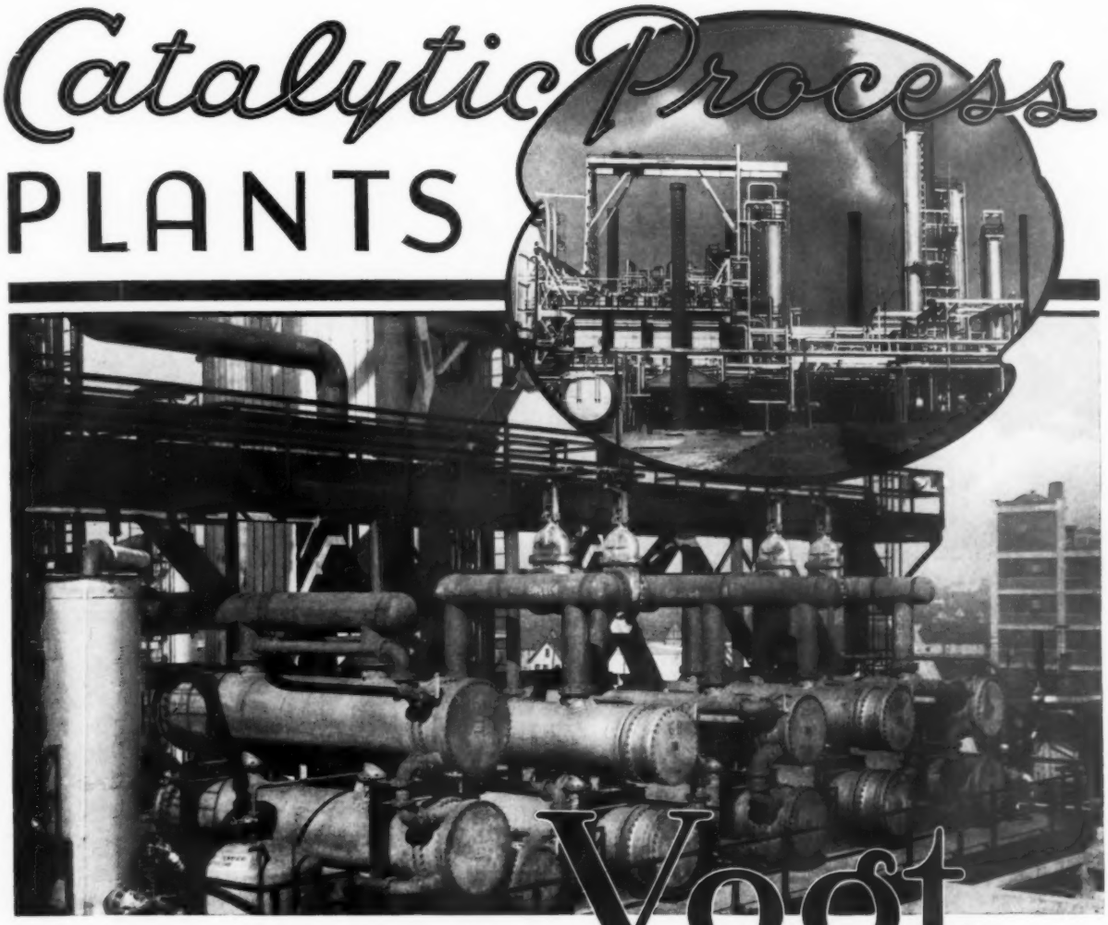

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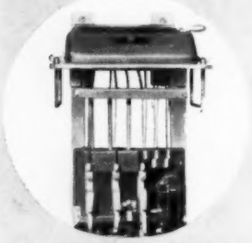
World Petroleum (including Petroleum Equipment Exporter), Vol. 11, No. 11, October 31, 1940. Entered as Second Class Matter, March 19, 1939, at the Post Office at Hoboken, N. J., under the Act of March, 1879. Additional entry at the Post Office at Orange, Conn. Published monthly November to September, Semi-monthly in October, by Russell Palmer at 95 River Street, Hoboken, N. J.

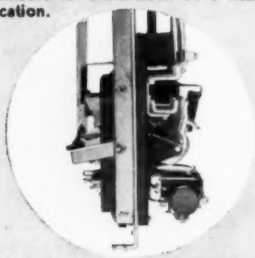
Announcing The NEW

3 IMPORTANT FACTS ABOUT THIS G-E OIL-IMMERSED STARTER

The corrosion-resisting cast-iron head is designed for making conduit connections from top, bottom, or either side. Installation is easy, expense is low.



The starter can be furnished with operating parts six inches under oil. When thus arranged, it is suitable for installation in a hazardous gas location.



The circuit breaker can interrupt a short circuit of 10,000 amperes. The breaker and the magnetic switch are mounted back to back. This arrangement is compact and is better able to withstand the mechanical stresses that a short circuit on the line might cause.

EASY TO INSTALL

The CR7008 oil-immersed starter consists of a magnetic switch for motor starting and a circuit breaker for disconnecting and for short-circuit protection. They come to you in one "package," to be installed as a unit—saving you time, trouble, and expense.

This starter is designed for wall mounting. It needs only four bolts. The cast-iron head, a new feature, keeps the case from the wall and enables you to make rigid conduit connections from *top, bottom, or either side*. The incoming and outgoing terminals have solderless connectors. The control terminals are furnished with a binding screw. All this makes for easy wiring. Two stainless-steel tank holders provide a simple means for attaching the tank.

ASSURES LOW MAINTENANCE, DEPENDABLE SERVICE

All operating parts, including the overload relays and the circuit breaker, are immersed in oil. Corrosive fumes cannot get at them. The cast-iron head, mentioned above, resists corrosive moisture that may condense on it. The case is of copper-bearing steel, painted with aluminum paint. The contactor tips are extra heavy and are reversible in the Size 2 and Size 3 starters, thus being good for twice the usual length of service. Flamenol wire, which is resistant to oil, is used thoroughout the switch in making connections.

EASY TO INSPECT

The operating devices are easily accessible. A special track arrangement on the inside of the tank facilitates moving the tank up and down. Hooks on which to hang the tank after it has been lowered are provided. You don't have to set the tank on the floor and run the risk of its being upset and spilling the oil.

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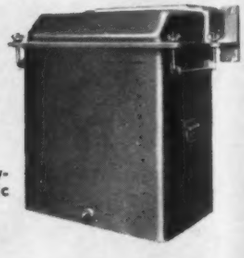


Type CR7006, low-voltage magnetic starter

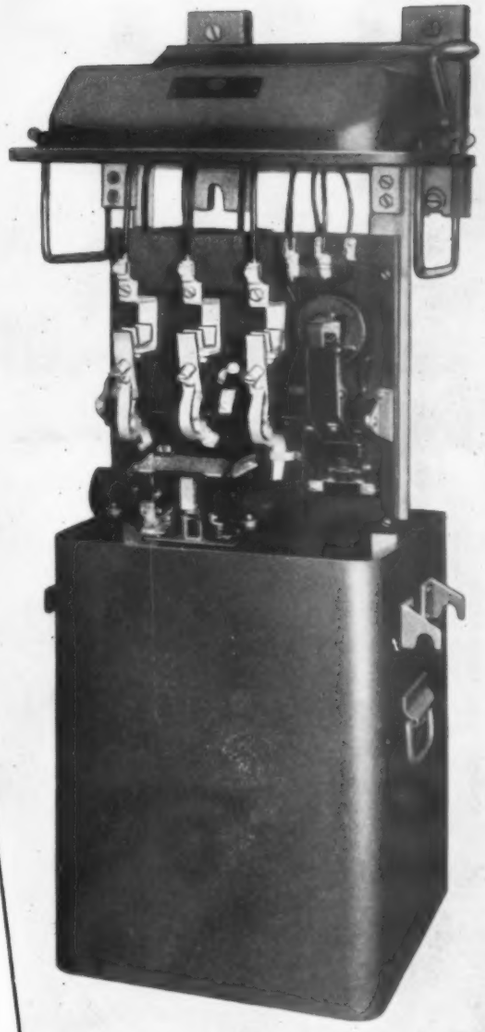
G-E OIL-IMMERSED COMBINATION STARTER

for Low-voltage Service

PROTECTS MEN AND EQUIPMENT

Thermal overload relays, specially designed for operation in oil, protect the motor against damage from excessive overloads. They are mounted with contacts at the bottom or side to prevent the possibility of oil sludge's interfering with their action. Under-voltage protection safeguards machines and operators from danger of unexpected restarting after a power interruption. The incoming terminals and the wires to the top of the circuit breaker are completely shielded so that an operator cannot make accidental contact with these live parts.

The new type of circuit breaker has a rating of 10,000 amperes and will interrupt short circuits up to that value. It is operated by means of a handle extending through the switch cover. The tank cannot be lowered unless this handle is in the "off" position, and power cannot be turned on until the tank is in place—an important safety feature.



HERE'S the oil-immersed control you've been asking for! This G-E CR7008 combination starter is now available for service with motors up to 30 hp at 220 volts, and 50 hp at 440 volts. It's packed with the features you want—new ones to meet the latest ideas and suggestions of operating men, old ones that have thoroughly proved themselves under actual operating conditions in refineries and chemical plants.

Decide now to install these new starters in your plant or refinery. Our nearest representative will be glad to go over your requirements with you. General Electric, Schenectady, N. Y.

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Type R1AA, high-voltage, normal interrupting capacity

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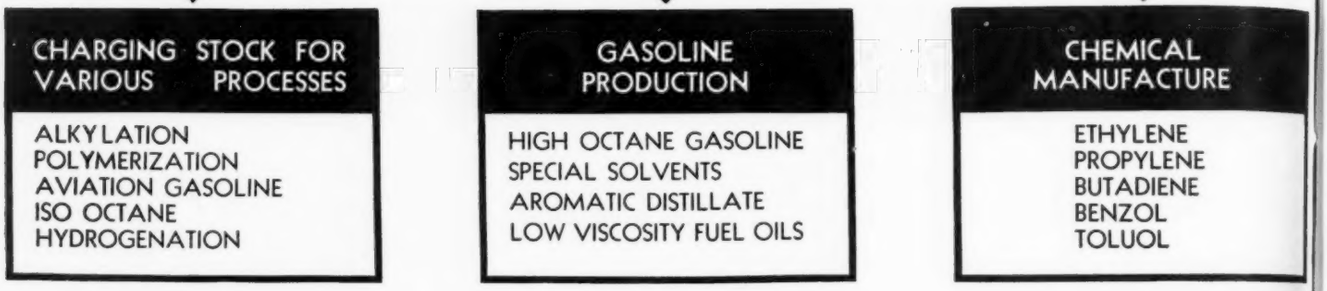

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COMMERCIAL GYRO operations have proven the versatility of the Gyro Process to meet the changing problems of today by producing products ranging from High Octane Gasoline for General Refinery Requirements to the production of Basic Chemicals and Charging Stocks for Special Processes.

MODERN GYRO UNITS range in size from Multi-Stage Cracking Operations, combining Two-Stage Viscosity Breaking, Vapor Phase Cracking, Reforming, Polymerization, and Treating, to Single Stage Units for the manufacture of Special Products from Selected Charging Stocks.

The **GYRO ROYALTY RATES** are no greater, and in many cases are less, than your present royalty rates, **irrespective** of the **number** and **type** of your present cracking units.

GYRO PROCESS COMPANY

Dime Bank Building
Detroit, Michigan

STRONG RIGHT ARM OF THE OIL INDUSTRY!

"Caterpillar" Diesel Engines and Tractors are making history in the oil fields, along the pipe lines, around the refineries. Oil men have seen their rapid strides—watched their popularity grow and grow. Where tough drilling jobs are being tackled—where the fight against time demands day-and-night going—where interruptions for power-plant repairs or overhauling may mean heavy profit losses . . . "Caterpillar" Diesel Engines usually get the call among far-sighted drillers. For these rugged, dependable, long-lived engines have thoroughly proved their qualities—with hundreds of records of satisfactory long-stretch performance. Drilling, lighting, string pulling, mud, well and line pumping jobs all look alike to "Caterpillar" Diesels—whether in Roumania, Iraq, Borneo, Venezuela, Colombia, or elsewhere.

Same way with the tractors: Rigging up and dismantling—moving equipment and hauling supplies—clearing sites and building roads—digging ditches, laying pipe and back-filling . . . there's nothing that can compare with "Caterpillar" Diesel Tractors.

They've the versatility for all sorts of jobs—traction that's sure-footed—power that hates to give up—stamina that enables them to keep at it with grim doggedness!

"Caterpillar" Diesel Equipment is backed by the most complete and readily available parts-and-service facilities of their kind in the world.

CATERPILLAR TRACTOR CO. • PEORIA, ILL., U. S. A.

Right, below — Two "Caterpillar" D17000 Diesel Engines operating mud pump and draw-works.

Left, below — "Caterpillar" Diesel D6 and D7 Tractors with Cardwell side-boom, laying 24-inch pipe with hot field bends through hilly country (sections up to 118 feet long).

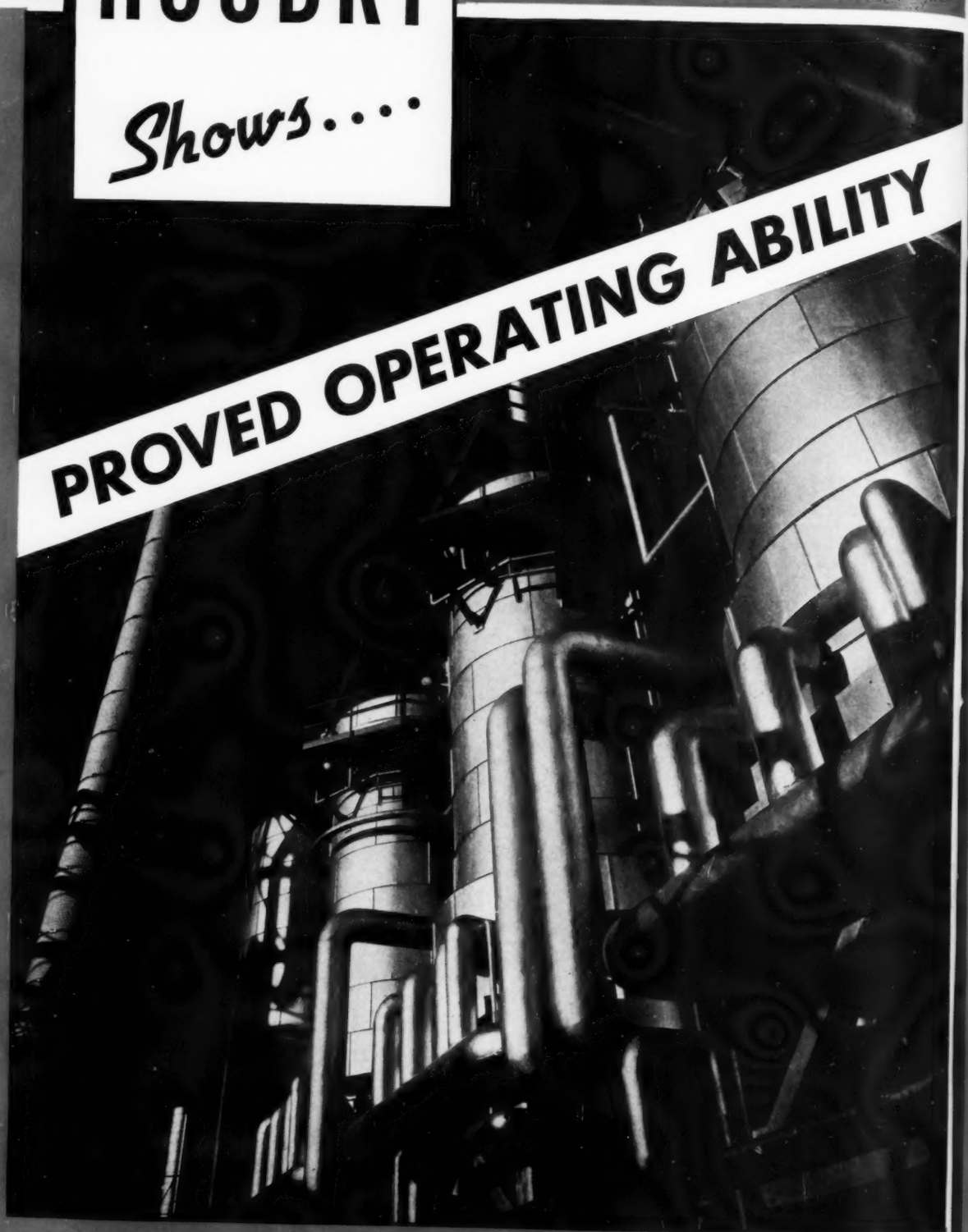
CATERPILLAR DIESEL POWER

Reg. U.S. Pat. Off.

TRACK-TYPE TRACTORS • ROAD MACHINERY
DIESEL ENGINES AND ELECTRIC SETS

HOUDRY

Shows....



HOUDRY SHOWS PROVED OPERATING ABILITY

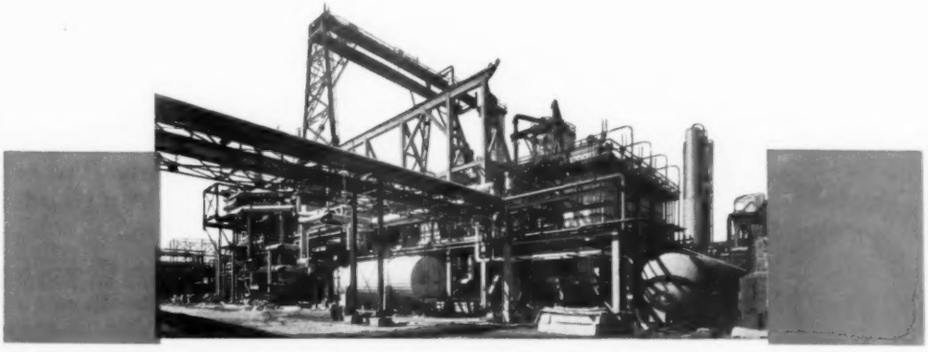
"On Stream"

A recently completed run shows the following, a record for any catalytic cracking unit:

On Stream	200 days
Gasoline	48.9% (once thru)
Octane (clear)	86 (39 Research)
Liquid Recovery	94.6%

. . . and another unit reported in August the completion of 157 days "on stream" with 96.6% time efficiency.

This proved operating ability combined with a proved ability to produce aviation fuel for national defense makes the Houdry Catalytic Cracking Process of *immediate* interest to all refiners.



Licensing Agents for the Houdry Catalytic Cracking Process

E. B. BADGER & SONS CO.

Boston, Mass.

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•

Engineers and Contractors
for Petroleum Distillation and Refinery Equipment

MODERN PYROLYTIC CRACKING PRODUCES QUALITY PRODUCTS WITH LOW PROCESSING COSTS

Cracking units licensed by Gasoline Products Company provide refiners with the latest accepted developments in pyrolytic cracking methods and equipment.

Accurate balancing of the various phases of crude distillation, viscosity breaking and cracking in a self-contained system offers distinct operating advantages. This, together with the adaptability of the system to various capacity requirements, assures the refiner of minimum operating and investment costs.

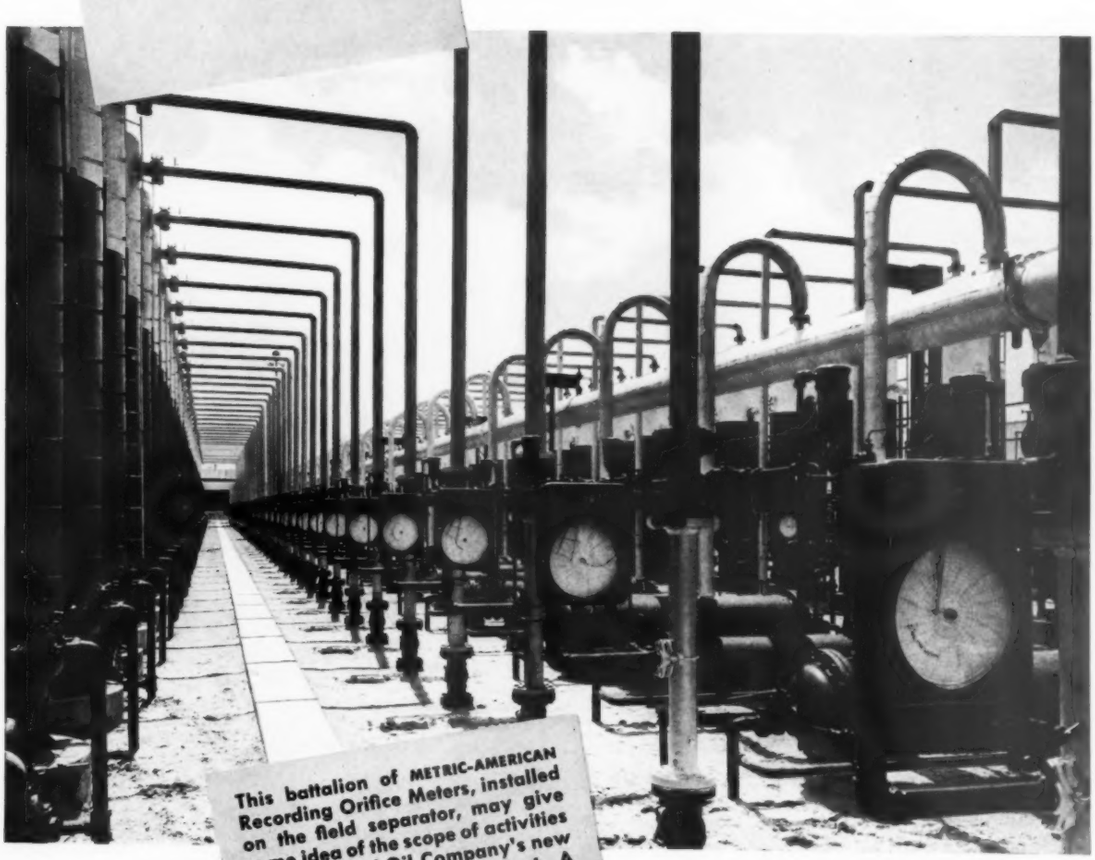
Gasoline Products Company is in a position to assist refiners in selecting the proper specialized cracking unit or combination unit to meet any particular processing problem.

GASOLINE PRODUCTS COMPANY, INC.

26 Journal Square · Jersey City, New Jersey

LICENSES granted under United States and Foreign Patents for: Cross, de Florez, Holmes-Manley, Tube and Tank Cracking Processes, Uni-Coil Injection Process and Combination Cracking Units
Licensing Agents: THE M W KELLOGG CO., Jersey City New Jersey, or its *European Representative* COMPAGNIE TECHNIQUE des PETROLES, 134 Boulevard Haussmann, Paris, France

INDUCTED INTO HARD SERVICE



This battalion of METRIC-AMERICAN Recording Orifice Meters, installed on the field separator, may give some idea of the scope of activities at Continental Oil Company's new Ville Platte (Louisiana) plant. A 8600-horsepower giant which sets new precedents in field stabilization, natural gas recovery and pressure maintenance!

METRIC-AMERICAN has seen service in many a Continental operation. The sustained fine accuracy of the Metric-American Orifice Meter under the most trying field conditions, has called it to service in oil fields and refineries throughout the world. Ease of inspection, cleaning and field adjustment . . . the exceptionally low maintenance cost . . . are factors in its choice. Engineers and maintenance men appreciate a practical instrument that does its job dependably without pampering.

Available upon your request: Helpful and complete technical literature on orific measurement and its modern applications.

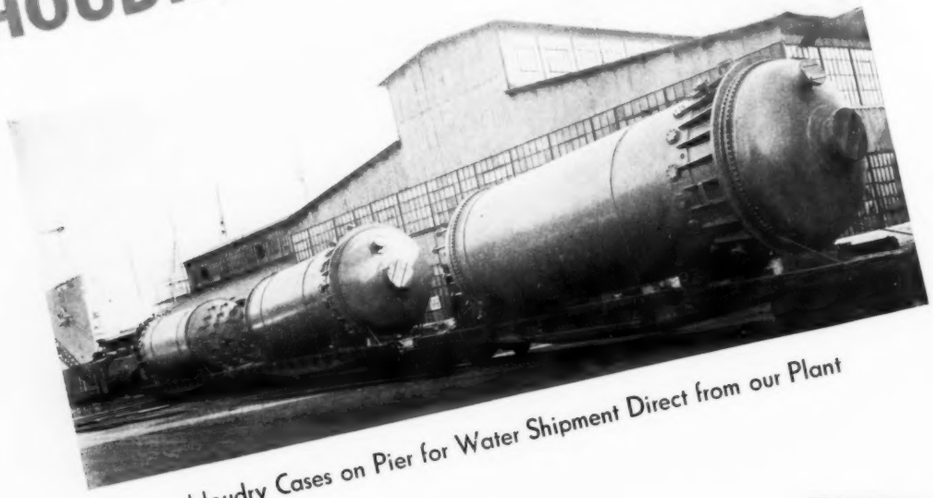
METRIC METAL WORKS • ERIE, PA.

AMERICAN
METER COMPANY
INCORPORATED (ESTABLISHED 1836)

1518

SERVING

EXCLUSIVE MANUFACTURERS OF HOUDRY CATALYTIC EQUIPMENT



Houdry Cases on Pier for Water Shipment Direct from our Plant

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Refining Equipment

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Builders of TANKERS

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All Sizes -- Any Speeds
Always Distinctive

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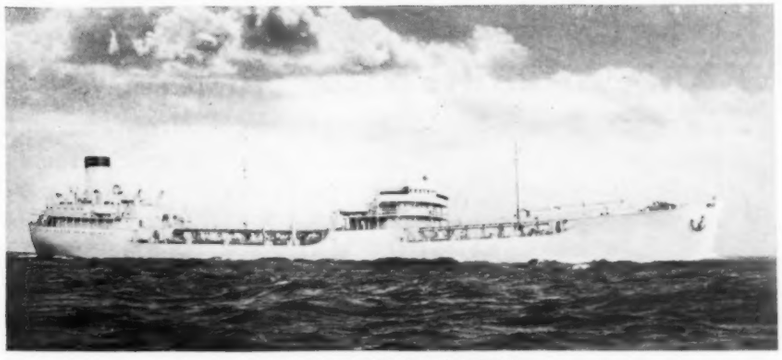

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RY DOCK COMPANY, Chester, Pa.

Valve Specialists

UP-TO-THE-MINUTE MACHINERY . . . Accurate gauges, jigs and fixtures assure quality products. Precision machining is a by-word at the Darling plant . . . just as Darling is the "buy-word" wherever quality gate valves are used.

BACKED BY 50 YEARS' EXPERIENCE. Every Darling Valve is built with the specialist's eye for design and performance . . . with the craftsman's pride in his work. Get the benefit of this specialized experience. Specify Darling!

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GATE VALVES

DARLING VALVE & MANUFACTURING COMPANY
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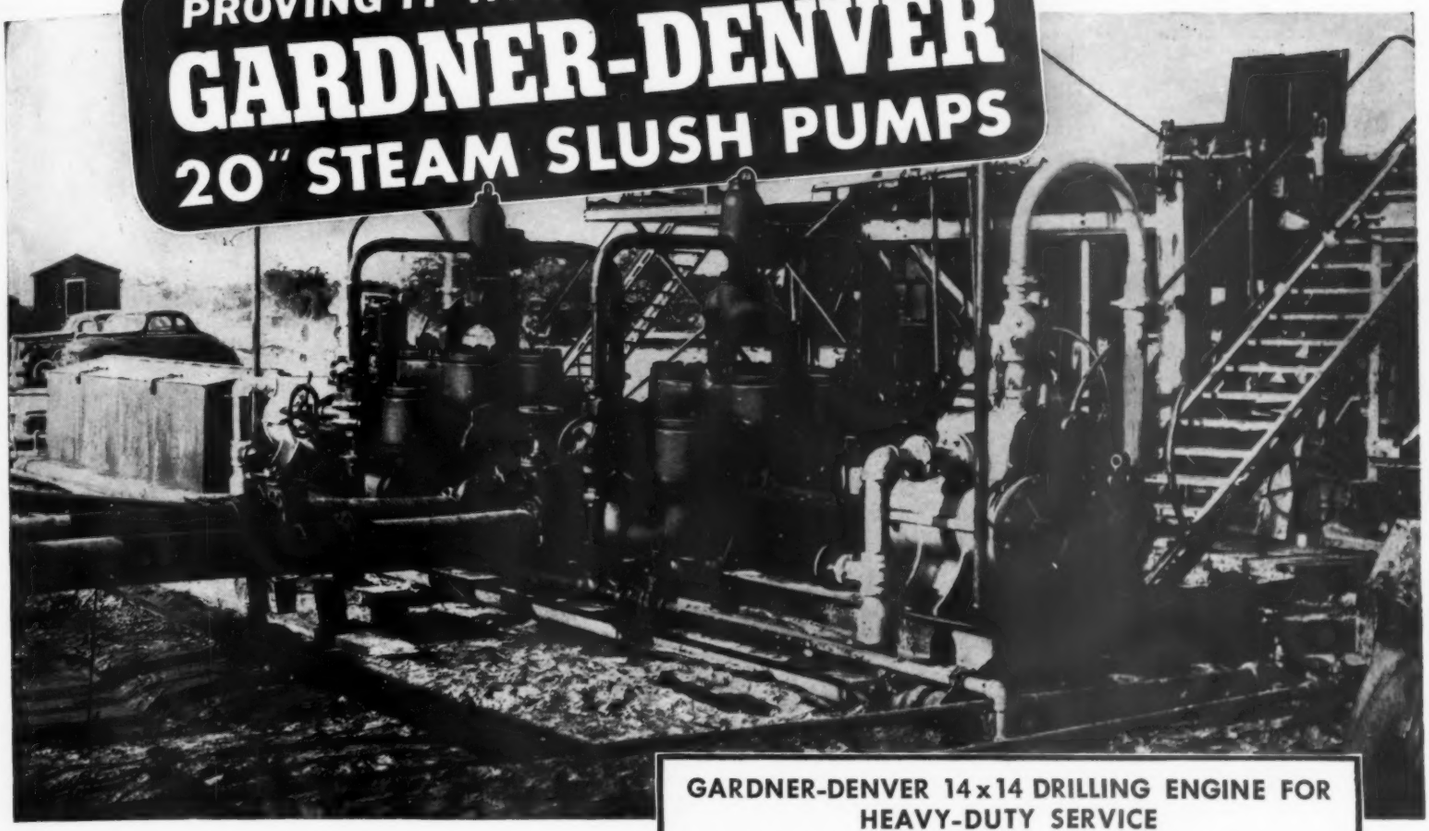
PROVING IT WITH PERFORMANCE—

GARDNER-DENVER 20" STEAM SLUSH PUMPS



RATING Steam cylinders designed for 400 pounds maximum pressure—8" maximum diameter fluid pistons—3000 pounds working pressure fluid end—6000 pounds test pressure.

SMOOTH RUNNING Improved Gardner-Denver divided fluid end—large, smooth suction manifold—streamlined with long radius, large area fluid passages into the valve pots, assuring less fluid friction, quicker filling and making higher suction lifts possible.

QUIET New enclosed roller bearing steam valve gear with telescopic levers is practically noiseless—see these pumps in operation and you will agree that they are the smoothest and quietest pumps built to date.

LONG-LIVED These pumps have Gardner-Denver "SLUSH PROOF" rods, liners and pistons—field-proved Gardner-Denver "SLUSH PROOF" duo-seat valves. Fluid cylinders are of "GarDurloy," a special alloy iron of high tensile strength—extremely resistant to pressure and to the abrasive action of slush—all features which contribute to a long life of economical, dependable operation.

For complete information write Gardner-Denver Company, Quincy, Illinois.

GARDNER-DENVER 14 x 14 DRILLING ENGINE FOR HEAVY-DUTY SERVICE

Rugged and *powerful* enough to drive the largest of present-day drilling equipment.

Economical in operating and upkeep costs because of high steam efficiency—enclosed construction to keep dirt and sludge out—fewer moving parts to wear—and forced oiling to all essential bearings.

SPECIFICATIONS GARDNER-DENVER 20" STEAM SLUSH PUMP

SIZE	Maximum Steam Pressure	Maximum Fluid Pressure with Master Liners
15½ x 8 x 20	400	1100
16¼ x 8 x 20	400	1200
18 x 8 x 20	400	1400
20 x 8 x 20	250	1100

All sizes may be furnished with reduced sizes of liners and pistons for higher pressures.

GARDNER-DENVER

SINCE 1859

DALLAS • HOUSTON • TULSA • ST. LOUIS • LOS ANGELES • SAN FRANCISCO
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30 ROCKEFELLER PLAZA, NEW YORK, N. Y.

For the production of High Octane Gasoline

ALKYLATION

90 per cent of the product of sulfuric acid catalytic alkylation is 90-92 octane C.F.R.M.

Foster Wheeler will contract for complete alkylation plants, including designs, fabrication and construction.

Installation and operation are much lower than with previous systems.

FOSTER WHEELER CORPORATION

POLYMERIZATION

H_2S REMOVAL

GAS AND LIQUID PHASES

Complete processes for the inexpensive removal of hydrogen sulfide—by regeneration of tri-potassium phosphate—are included in these new polymerization plants.

Catalytic Polymerization provides an increased yield of high octane gasoline without increasing crude consumption.

The large polymerization plants now under construction are by Foster Wheeler.

165 BROADWAY, NEW YORK, N. Y.

WHEELER

INTERNATIONAL PETROLEUM COMPANY

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Producers, Refiners, Distributors, and Marketers of Petroleum and Petroleum Products in the Republic of Peru

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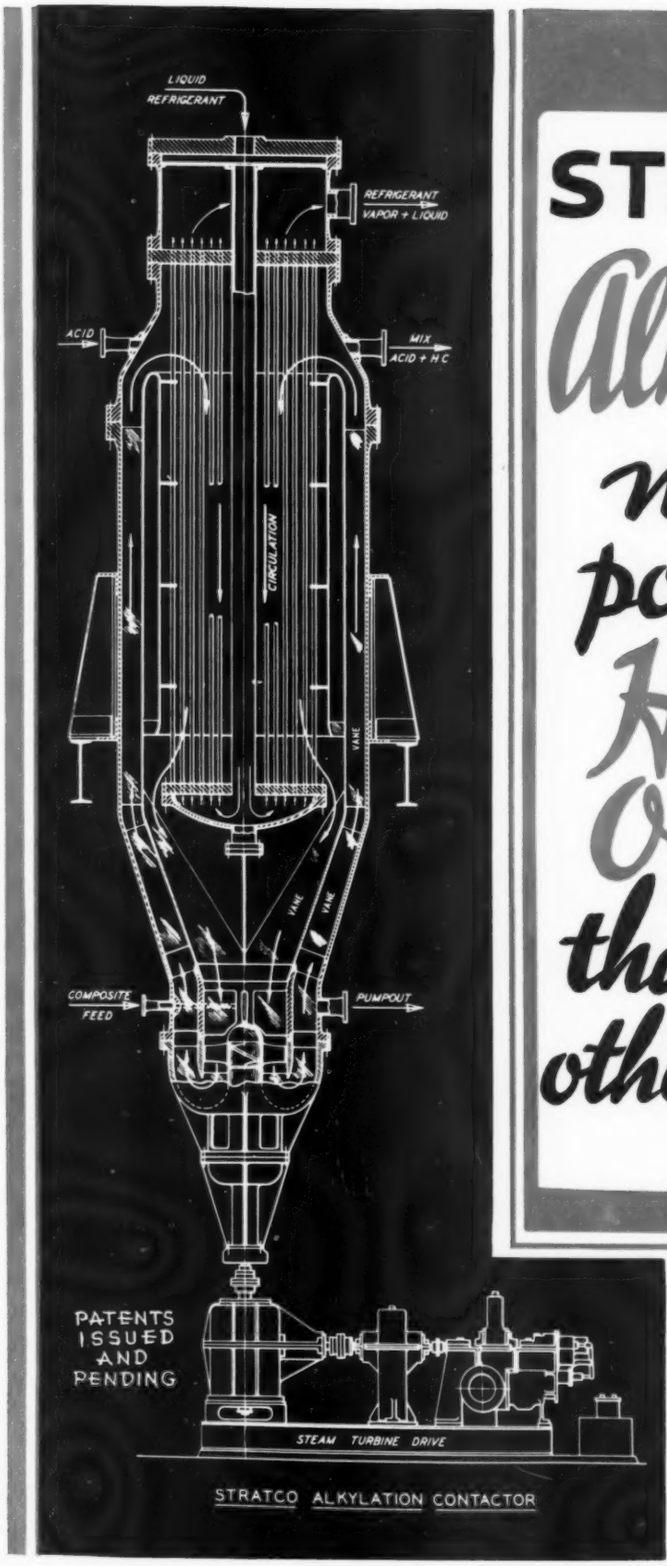

STRATCO ALKYLATION CONTACTOR

STRATCO

Alkylation makes possible Higher Octane than any other method

STRATFORD ENGINEERING CORPORATION

DIERKS BLDG.
KANSAS CITY,
MISSOURI

Worthington LTC angle gas engine compressor, available in six sizes, 375-hp. to 1000-hp.

Three 225-hp. and two 300-hp. Worthington angle gas engine compressors, in a refinery cracking plant

One of two Worthington 8-cylinder 1000-hp. convertible gas-Diesel engines, in general power service

Worthington 180-hp. vertical gas engine, for auxiliary service, in a mid-western oil pipe line station

Worthington centrifugal hot charge pump, driven by Worthington vertical gas engine, in an eastern refinery

Two Worthington Type H centrifugal pumps handling hot oil, in a recycling plant

One of three Worthington duplex pumps, motor-driven, pumping cold oil at 1500 p.s.i. discharge pressure

Two Worthington centrifugal pipe line pumps driven, through fire wall, by Worthington 280-hp. Diesel engines

Worthington-Carbondale chilling machines, for ammonia direct-expansion operation in a solvent dewaxing plant

Worthington angle refrigeration compressor with ammonia cylinders in a dewaxing plant

Worthington horizontal duplex power pumps on water repressuring service

Hydraulic decoking systems for removal and transportation of coke from coke chambers in refineries

Worthington rotary pump, gas-gasoline engine driven, in gathering service in the oil fields

Worthington HiVoL direct-acting pumps, handling gasoline, in refinery service

Worthington centrifugal pumps in line, driven by Moore steam turbines, in oil refinery service

Worthington power pump driven by gasoline engine with Worthington Multi-V-Drive, in oil gathering service

Production • Transportation Refining

THE installations illustrated here exemplify the complete coverage of Worthington power and pumping equipment for field, pipe line and refinery . . . for every service condition. A fast growing list of Worthington installations . . . for every petroleum industry function . . . is but logical recognition of consistently efficient performance, in every application.

DIESEL AND GAS ENGINES
CONVERTIBLE GAS-DIESEL ENGINES
MOORE STEAM TURBINES
SPEED CHANGE GEARS
REFRIGERATION EQUIPMENT
AIR CONDITIONING EQUIPMENT
GAS COMPRESSORS
AIR COMPRESSORS
CENTRIFUGAL PUMPS FOR EVERY USE
STEAM PUMPS
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ROTARY PUMPS
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VACUUM PUMPS
FEEDWATER HEATERS
PRESSURE FILTERS
LIQUID METERS
MULTI-V-BELT DRIVES
PORTABLE AIR COMPRESSORS
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Literature on request

WORTHINGTON PUMP AND MACHINERY CORPORATION

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from STRENGTH

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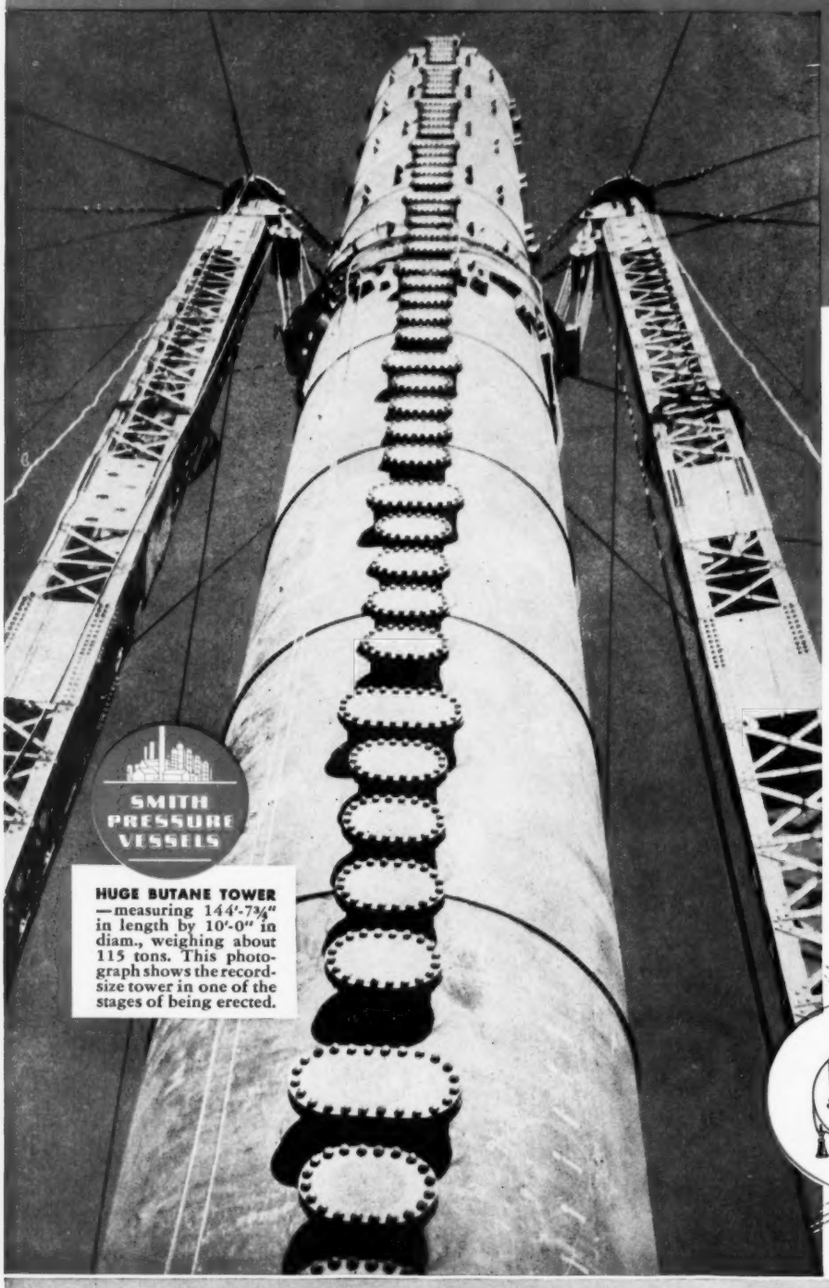
We also make **STAINLESS** STEEL BOLTS *by a new and improved process*

A.P. NEWALL & CO, LTD.

POSSILPARK ☆ GLASGOW.N.

NO PRESSURE VESSEL JOB *Is Too Big for* SMITH



HUGE BUTANE TOWER —measuring 144'-7¾" in length by 10'-0" in diam., weighing about 115 tons. This photograph shows the record-size tower in one of the stages of being erected.

THIS huge pressure vessel, towering nearly 145 feet into the sky, was built for one of America's great refineries by A. O. Smith. In size it is typical of other pressure vessels now under construction in the Smith plant—some of them with diameters as great as 18 and 20 feet. Many of these vessels are completely finished in the Smith plant; some are built in sections and shipped knocked-down for erection in the field. Many are Smithlined with various alloys for different service requirements.

The petroleum refining industry turns to Smith for a large portion of its pressure vessels, because Smith's facilities for the construction of such vessels are unequaled . . . and because the Smith method of dealing with corrosion problems *individually* has proved to be the most satisfactory.

A. O. Smith Corporation, Milwaukee, Wisconsin. Offices at: New York, Pittsburgh, Chicago, Tulsa, Dallas, Shreveport, Houston, Corpus Christi, Los Angeles.

DID YOU KNOW?

- A. O. Smith, founded in 1874, is the *largest producer* in the world of big, single-piece, glass-lined tanks.
- Brewery stock houses, equipped with glass, are now far more *economical* because of Smith contributions.
- Among these contributions is the *Smith blue glass*—smooth and lustrous, simplifying cleaning—the ultimate in sanitation.
- 5000 Smith craftsmen, in an ultramodern 125-acre plant, produce *50 million pounds of steel products* monthly.

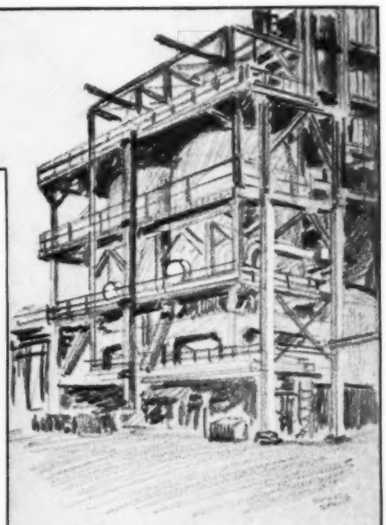
A.O.SMITH
CORPORATION
Milwaukee, Wisconsin

PIONEER MANUFACTURERS OF ELECTRIC-WELDED

Pressure Vessels

Casing · Line Pipe

. . . ON THE WAY TO THE SITE OF A MODERN GASOLINE PLANT
Wyatt's



A BASICALLY SOUND PROCESS

For sixteen years the Gray Clay Treating Process has been used by refiners to treat naphthas produced from different cracking processes. Operating records prove it sufficiently flexible to handle any variations in cracking conditions.

Equipment required is of simple construction. Installation cost is moderate. Adsorbent cost is low. Operation entails a minimum of attention. Maintenance is negligible.

Refiners operating units having capacities ranging from 100 barrels to thousands of barrels per day, find the Gray Process a highly satisfactory method of producing at low cost and without loss of octane number a stable low gum content gasoline.

A REFINING PROCESS WITHOUT CHEMICALS

This is an accurate description of the Gray Process because the undesirable gummy materials are removed by Polymerization without the loss of desirable gasoline or octane rating.

THE GRAY PROCESSES CORPORATION

Licenses granted under United States and Foreign Patents by The Gray Processes Corporation

26 JOURNAL SQUARE · JERSEY CITY, NEW JERSEY

GRAY

CLAY TREATING

THOUSANDS OF INSTALLATIONS of Johns-Manville Insulating Materials are giving dependable service . . . keeping operating costs low. From the complete line of J-M materials, you can select the right insulation for every type of heated or refrigerated equipment.

Will Your Insulation Investment Keep on Paying a FULL Return?

INSULATION OF ANY KIND is bound to cut fuel costs the first year it's in service. But it's *after* that time that the real test comes. If the insulation is to do a *complete* job, *returns in the form of fuel savings must continue indefinitely at their initial high rate.*

Because Johns-Manville Block Insulations deliver just such savings year in and year out, refineries all over the world rely on them to keep operating costs at minimum figures. Check these advantages that the proper J-M materials, properly applied, bring whenever used:

- ***J-M Block Insulations do not compress during application. Thus, you are sure of obtaining the full thickness specified. And they do not sag or decrease in thickness throughout the life of the equipment to which they are applied . . .***
- ***Their uniform strength and durability guard against structural damage or impairment of their insulating effectiveness...***
- ***Efficient to begin with, J-M Insulations maintain their original high insulating efficiency in service . . .***

Before you insulate any heated or refrigerated equipment, it will pay you to investigate the complete line of Johns-Manville Insulating Materials. For details, write Johns-Manville, 22 E. 40th St., New York, N. Y.

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INDUSTRIAL INSULATIONS

For every temperature . . . for every service

Superex . . . 85% Magnesia . . . Asbesto-Sponge Felted . . . Sil-O-Cel C-22 Brick . . . JM-20 Brick . . . Sil-O-Cel C-3 Concrete . . . No. 450 Cement . . . Rock Cork

In New Zealand

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JOIN THE BIG FAMILY of International owners next time you buy trucks—and enjoy the *performance* and *economy* these units will give you over *a long period of years.*

There's *real satisfaction* hauling your loads with Internationals. That's because this organization *knows how* to build trucks for the tough work in the oil business—trucks that are *all-truck* all the way through, readily adapted to all types of loads, and able to lick the hardest going.

Depend on Internationals for outstanding service at lowest possible cost. Find out all about the types and sizes best suited for your work. The nearby International Dealer or Branch will give you complete information. Sizes from Half-Ton units up to powerful Six-Wheelers.

INTERNATIONAL HARVESTER COMPANY
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International Pickup trucks provide fast transportation for a wide variety of light-hauling work in the fields and every other branch of the industry.

Above: An International used by Lane-Wells Co., Los Angeles, shown on location near Bakersfield where the crew was shooting casing.

Right: Smith Bros., hauling contractors in the Illinois fields, give their tough jobs to Internationals.

INTERNATIONAL TRUCKS

In any emergency

Knowledge and experience that are serving the refiners of the world so well in normal times will be doubly important to this Nation in an emergency

U. O. P.'s organization constitutes a General Staff of specialists in important fields including:

Pyrolytic cracking	*Alkylation*
Pyrolytic reforming	*Isomerization*
Catalytic cracking	*Cyclization*
Catalytic reforming	*Aromatization*
Polymerization	*Dehydrogenation*

These processes are used for the production of motor fuels, including aviation gasoline of highest octane rating, and other products Among these are toluene, the base for making T. N. T., and butadiene, a base for making synthetic rubber

Universal's experience and achievements of a quarter of a century and its future developments are at the industry's service to help meet any emergency

Universal Oil Products Co
Chicago, Illinois

Dubbs Cracking Process
Owner and Licensor

TEXACO DEVELOPMENT CORPORATION

PATENT LICENSES IN THE PETROLEUM INDUSTRY

TEXACO DEVELOPMENT CORPORATION

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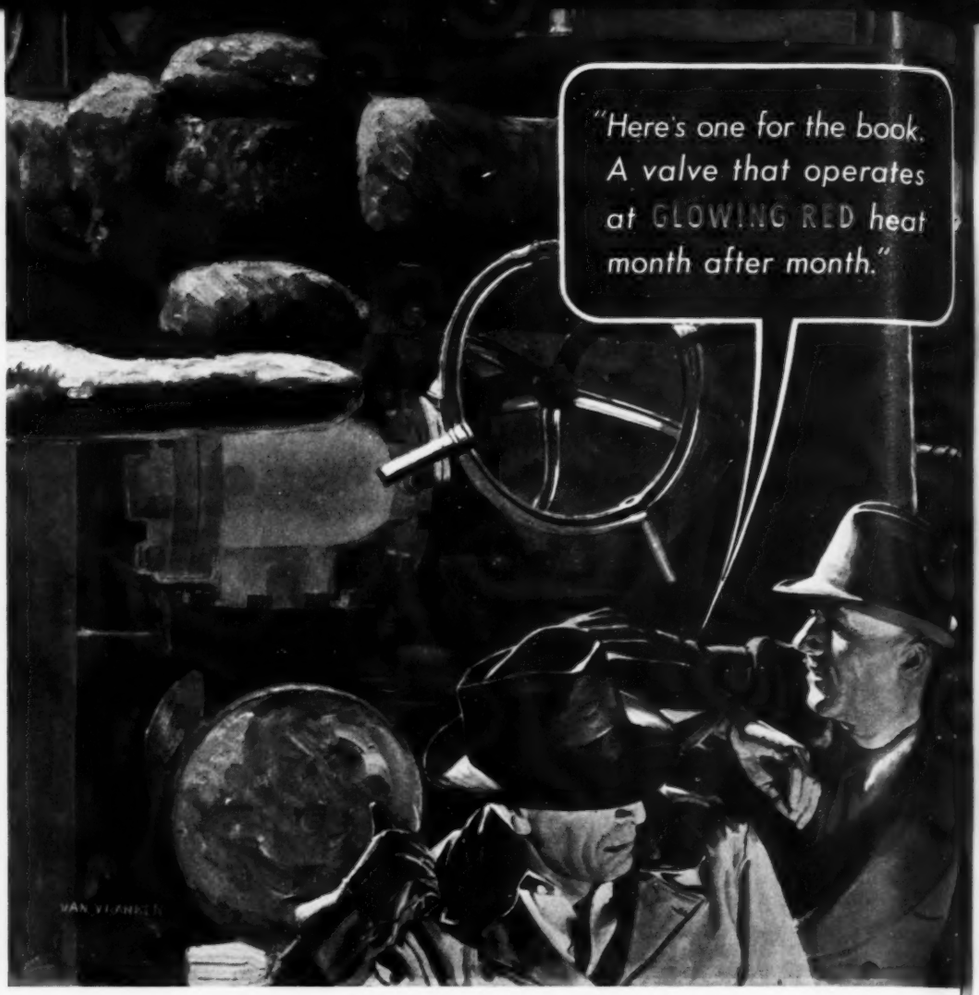
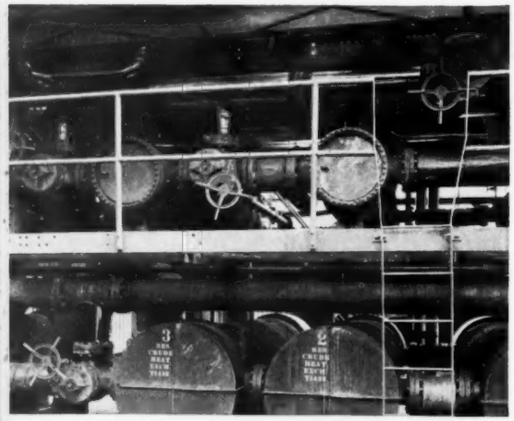
...the new

NORDSTROM MERCHROMED *Valves*

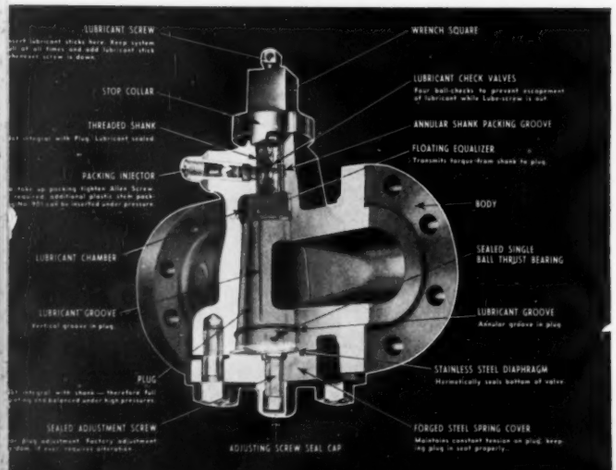
...for extreme conditions of TEMPERATURE, CORROSION and EROSION





Nordstrom Merchromed 8" Multiport Switching Valves on heat exchangers in a mid-west refinery.

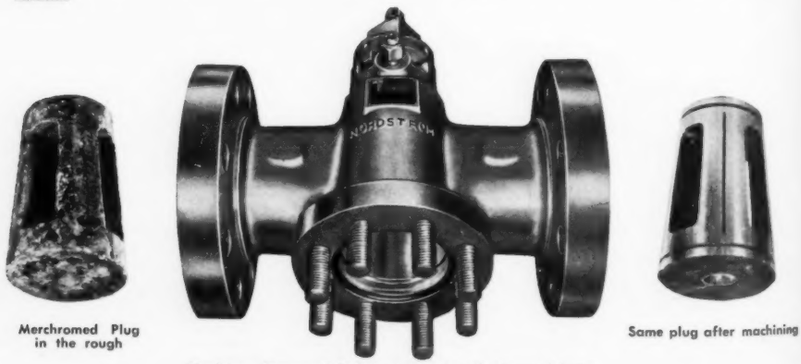
Below: Nordstrom Hypreseal Valve.



HANDLING TEMPERATURES AS HIGH AS 1000° F.

Nordstrom Merchrome Coated Valves are the latest advancement. By a highly technical metal alloy process the plug and body are protected by an impenetrable coating which prevents galling and scoring in temperatures as high as 1000° F. The Merchrome Process (patent issued) is a development in which a welded coating is applied to the surfaces of the rotating plug and the interior of the body, and in some cases other parts of the valve. This extremely hard coating has the highest corrosion-resistant properties. Moreover, it retains these properties at extremely high temperatures. An invaluable characteristic is its extremely low coefficient of friction. This quality is of particular advantage at high temperatures. The hardness of Merchromed surfaces is in excess of 50 on the Rockwell C Scale. The corrosion-resistance is approximately equal to that of the most corrosion-resistant stainless steels. The Merchromed coating forms an inseparable bond which may be applied in any thickness. Merchrome Valves open an entirely new field of service in refineries where temperatures run from 500° to 1000° F. For high temperature service the plugs on Nordstrom Merchrome Coated Valves are specially "hot-lapped" into the bodies at a temperature corresponding to the service for which they are intended.

Performance records indicate an extremely long life for valves, Merchrome Coated. Many refineries have already adopted Nordstrom Valves with this remarkable coating. Ask for full details.



Merchromed Plug in the rough

Same plug after machining

Nordstrom Hypreseal Multiport, showing Merchromed Body

MERCO NORDSTROM VALVE CO.

A Subsidiary of PITTSBURGH EQUITABLE METER CO.

WORLD'S LARGEST MANUFACTURERS OF LUBRICATED PLUG VALVES; GASOLINE, OIL & GREASE METERS

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South American Representative: The Armco International Corporation, *Main Office,* Middletown, Ohio.

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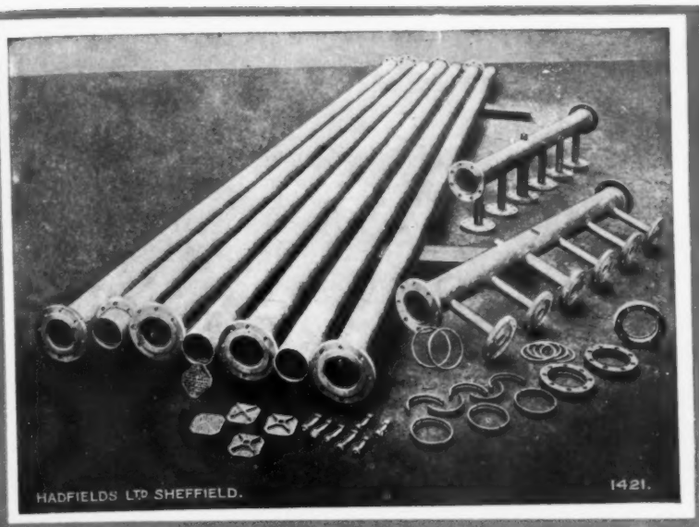

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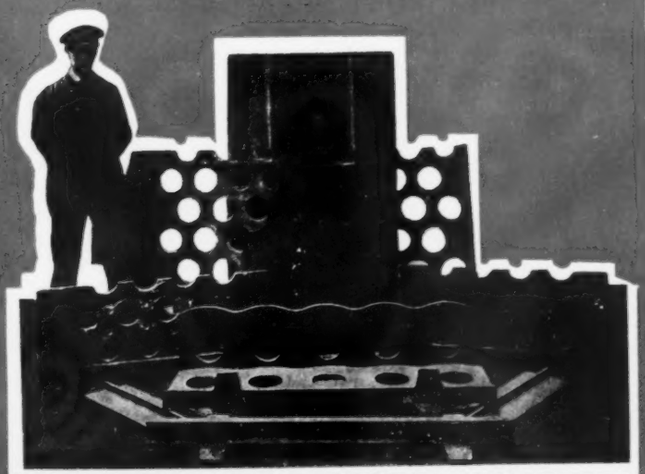

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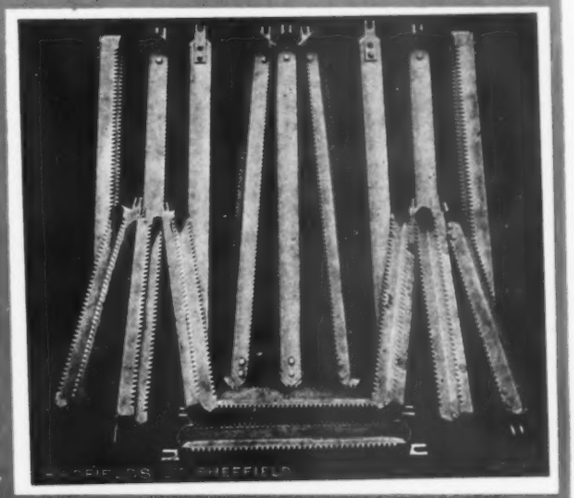

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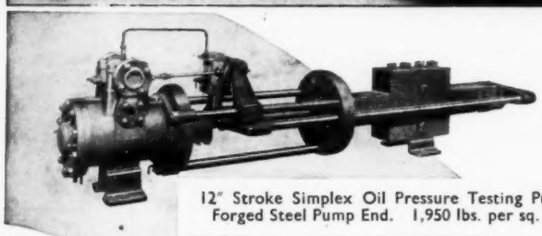

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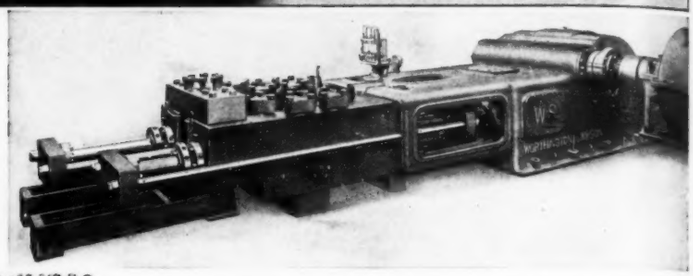

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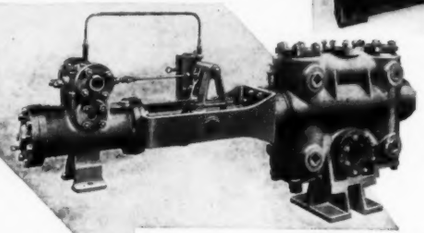
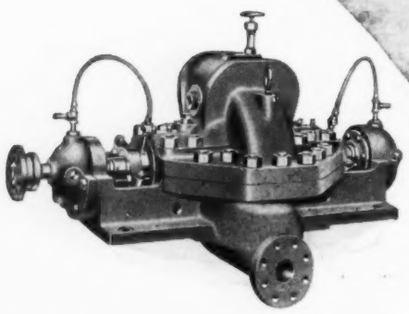
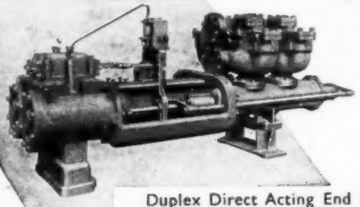


Close Clearance Extraction Pump with Steam Jacketed Pump End.





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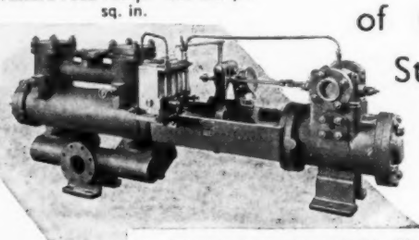

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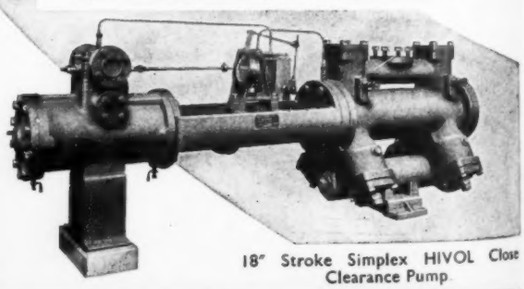

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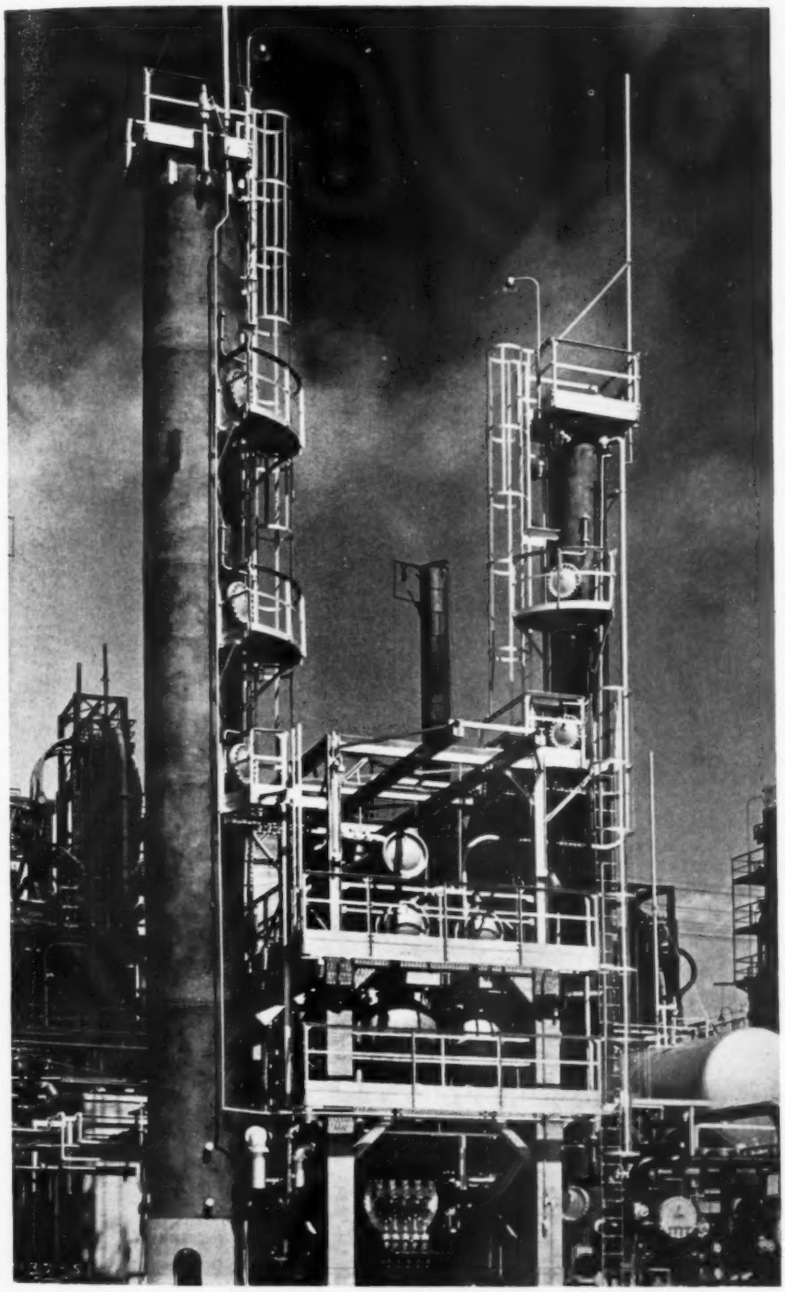

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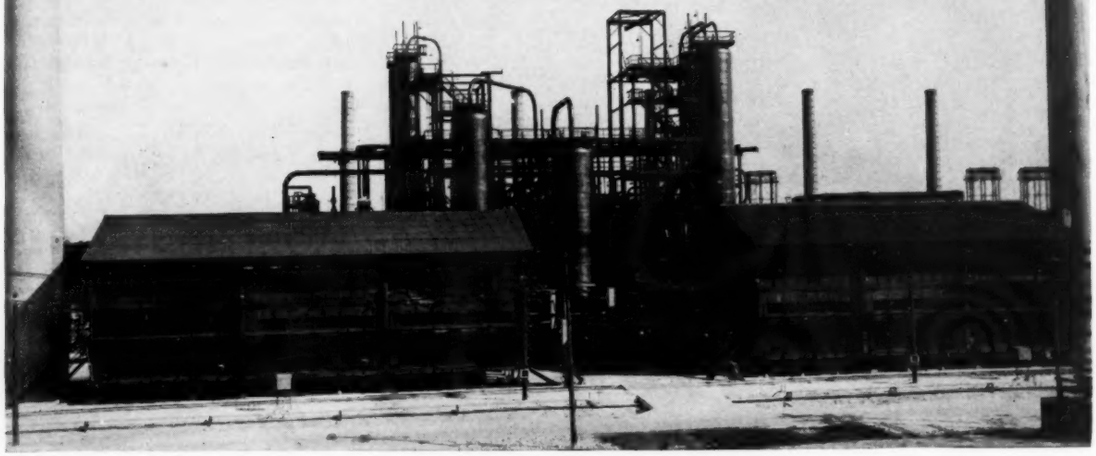

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VOLUME 11 | **OCTOBER 31, 1940** | **NUMBER 11**

WORLD PETROLEUM: Incorporating Petroleum Equipment Exporter

CORRESPONDENCE

Address all correspondence regarding editorial, advertising, subscription and business matters to the Home Office; 95 River Street, Hoboken, N. J. Telephone Rector 2-2043 or Hoboken 3-2480.

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Annual subscription to World Petroleum is offered at the flat rate of five dollars (U. S.) postpaid to any country in the International Postal Union.

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Subscriber's name and address should be in Roman capitals on the subscription order.

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British subscribers may make payments at the London office of World Petroleum. Monthly copies, two shillings; yearly, one guinea.

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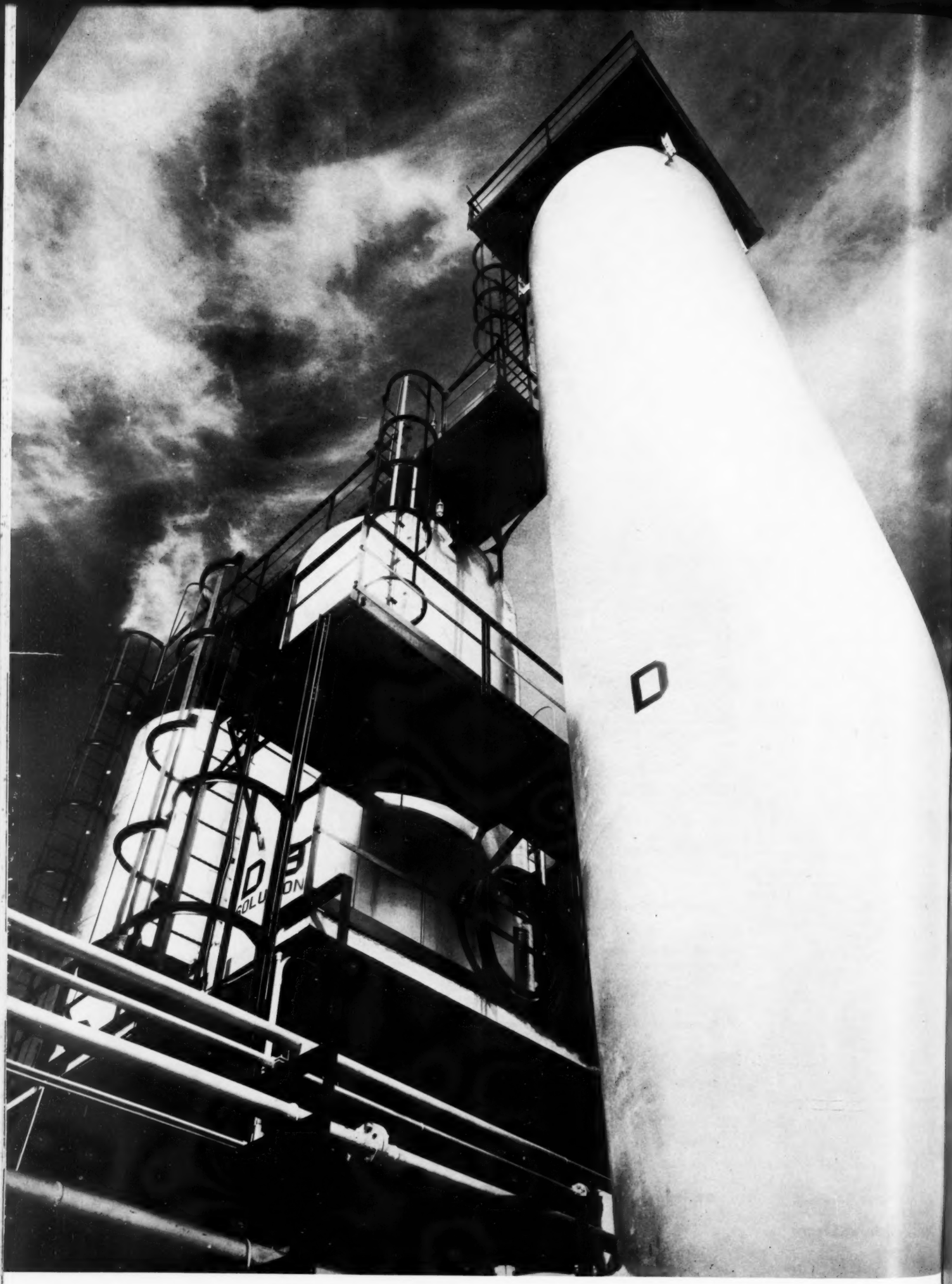


Shell's Wood River Refi

EDITORIAL

REFINING INDUSTRY CAN ANSWER "READY"

THROUGHOUT its history the refining industry has been a willing instrument of public service. While developing its own facilities, discovering new processes and finding new uses for its products it has revolutionized the world's systems of transportation, has made possible the creation of vast new industries and has served as the most important and most practical force for petroleum conservation.

For many years the most urgent problem confronting the refiner was to provide increasing quantities of fuel demanded by the swift expansion of the motor age. As the requirements doubled and trebled heavy inroads were made upon existing oil reserves and the possibility of their early exhaustion became an alarming one. Then came the cracking process by which the recovery of gasoline from a barrel of crude was doubled within the space of a few years. In 1900 it was possible to recover 5.4 gallons of gasoline from a 42-gallon barrel of crude. By 1920, when cracking systems were just coming into use, the recovery of gasoline had increased to 10.8 gallons. Today it is possible to convert into motor fuel more than half the volume of crude and the search for further improvement is still going on. Except for the development of this process it would require over 4,400,000,000 barrels of crude to satisfy the yearly world demand for gasoline instead of the 2,200,000,000 barrels actually used.

Not all other conservation forces combined, can begin to approach this record for preserving natural deposits of petroleum for future use.

Along with this remarkable achievement has gone a great improvement in the quality of motor fuels and lubricants so that the performance of internal combustion engines is beyond comparison with those of a quarter century ago. Along with it has gone also a vast multiplication of useful products evolved by progress in the refining art and a truly remarkable advance in the utilization of former waste products.

Discussing the trend of the refining art in these pages two years ago attention was directed to the change then taking place in refining activities and particularly in its research to which more and more attention was being directed year by year. As was stated then emphasis was being placed on the processing side of the industry as the one showing greatest possibilities of advancement.

Today the work of these past years, work on which the oil industry unaided has spent hundreds of millions of dollars, is bearing fruit of inestimable value. In the great work of national defense oil plays a vital part, no less than the planes, ships and armament which would be useless without it. As usual the oil industry is prepared. It was ready to supply the products required for national preparedness when the call came and to start instantly on the expansion of facilities to increase its output of such products to any extent necessary.

Not only is the industry equipped to function efficiently in the provision of its customary products such as aviation fuel, lubricants, gasoline and fuel oil, but it is being called upon and already is on the way to providing products such as synthetic rubber which might be unobtainable from customary sources in the event of war and also explosives and other chemical supplies essential to military operations. Should war be forced upon the United States the petroleum industry would play a far greater part in defending the nation and in making it powerful on offense than it did in the days of 1917-18.

For this fortunate position all credit is due to the army of petroleum chemists, engineers and other research workers who have labored in past years and are working even more assiduously now to discover and bring to practical utility new forces contained within that magic substance, oil, to raise the quality and efficiency of its regular products, to utilize former wastes and to contribute added strength to other industries outside their own immediate sphere. Like credit must go also to the management of American oil companies for appreciating the value of such research and experimentation and providing the means for keeping it steadily in operation against the time of need which is now arriving.

ADVISORY COMMISSION Finds No Immediate Refining Problems

Only Proposals Initiated by Private Concerns Are Actually Being Realized—Government Agencies Continue Studies But Anticipate No Major Construction for Oil Other Than Military Storage.

WASHINGTON, D. C

IN the opinion of the National Defense Advisory Commission the refining of petroleum and its products offers no immediate problems in meeting both the developing requirements of the Army and Navy and the normal additions to civilian consumption.

Only in the matter of long-range planning, which looks towards an increase in the capacity for production of 100-octane aviation gasoline and the requirements occasioned by the projected two-ocean navy does any large scale expansion of refining facilities enter into the present picture if exception is made of several experimental projects.

These include the development of butadiene for use in making synthetic rubber, of tuluol or toluene, essential in the manufacture of the highly important explosive TNT and a project to standardize the grades of lubricating oils to simplify the Army's transport problems.

In the confusion which has accompanied the sudden efforts to coordinate the sprawling procurement plans of the Army and Navy, none of the proposals, expect where carried out by private initiative, has gone beyond the conference stage although one contract for plant installation by the Humble Oil Company of Texas for the manufacture of toluol has been drawn by the Ordnance Bureau of the War Department, but thus far remains unsigned despite approval by the Defense Commission.

Whether the government, through the Defense Plants Corporation, established by the Reconstruction Finance Corporation, decides, on the basis of plans now under discussion by interested groups, to undertake the financing of synthetic rubber on a large scale is conjectural. Apparently, the intention for the present at least, is to await the results of projects now under way which were originated and are being developed by private initiative.

Among these are the plant of Hydrocarbon Chemical and Rubber Company, joint enterprise of Phillips Petroleum Company and Goodrich Rubber Company and the unit installed by Standard Oil Company of Louisiana at its Baton Rouge refinery. The whole question of synthetic rubber production is one that representatives of the government are watching carefully. It is realized that conditions may arise which will make it necessary for the government to undertake a major effort in this field.

To date nothing definite has been worked out in the Reconstruction Finance Corporation discussions although Federal Loan Administrator Jesse H. Jones recently observed that he guessed the government probably would have to act on the matter. Also heading up in the R. F. C. is the project to provide large and widely-distributed storage facilities for aviation gas and other motor fuel which the Army, Navy and Defense Commission hold should be given priority over other oil developments in which the government may be expected to take a hand. The storage financing project also is in the hands of Administrator Jones.

Although toluene was one of the bottlenecks of the last war, E. R. Stettinius, Jr., in charge of the Industrial Materials Division of the Defense Commission, is convinced that "our present position is in sharp contrast with the situation then prevailing." His opinion is based on a study made by the commission in conjunction with the Army and Navy.

The study showed that present commercial needs of toluene for paints, lacquers, and other material can be met by recovery from by-product coke-ovens (see page 88) and that experimental production of toluene from petroleum indicates an "entirely practical source of supply".

> "Large volumes," continued the report, "can be made available in a relatively short time by the installation of additional recovery equipment. The regular commercial needs now can easily be met by recovery from by product coke-ovens, and the petroleum industry will be able to produce more than enough for expected military purposes."

Two new toluol plants are under construction and a large expansion of production can be provided on relatively short notice. Domestic demand which absorbs over two-thirds of the entire production in the United States is customarily relatively stable and no significant increases are currently in prospect. Foreign demand has shown a tendency to decline as important European markets have been shut off by the war.

In 1939, approximately 25,000,000 gal. of toluene were produced in the United States. Since activity in the steel industry began to expand last fall, production of toluene from coke-ovens has increased.

> "Of the two methods of getting by-product toluene from petroleum," said the report, "the more important is the recovery in the production of high-octane gasoline. It is estimated that supplies can be made available by this method at costs comparable to those prevailing at the coke-ovens."

The second and more costly method, which could be used, if emergency conditions requires it, involve the "cracking" of other petroleum products. Experimental production of toluene from petroleum has indicated that this is an entirely practical source of supply and that large volumes can be made available in a short time by the installation of additional recovery equipment.

> "During the first world war, capacity for the production of toluene was nearly doubled, increasing from 12,000,000 gal. in 1917 to an estimated 23,000,000 gal. by December 1, 1918. At that time nearly half of the supply came from water gas plants. Since then these facilities have been reduced substantially, but capacity at by-product coke-ovens has nearly tripled.
>
> "As a few months' time is required to install recovery and purification equipment at petroleum refineries, it is recommended that a 'stock pile' of toluene be acquired in order to prevent the possibility of temporary shortage in this very essential raw material. Plans should be formulated to provide necessary quantities of toluene through the collaboration of the petroleum industry and the operators of by-product coke-ovens and water gas plants. Supplies for some time can be made available through existing facilities and as military needs expand additional capacity will be brought into use."

The Defense Commission estimates that a major war effort would require no more oil than the amount which would constitute the two-year increase in ordinary domestic requirements. For that reason the ability of the refining phase of the industry to cope with the developing situation is not questioned. Any increase, if undertaken, will be in the facilities for the production of aviation gas and alterations which may be required to supply fleets in both the Atlantic and Pacific oceans. Both steps are envisioned here but neither is in the prospectus stage due to the uncertainties regarding the requirements of the air forces and the Army's mechanization on one hand and the Navy's plans for fueling its expanded fleet on the other, which, after all is a contingency to be met in future years. While the Navy has requisitioned several tankers recently this does not necessarily signify an early increase in its fuel requirements. Some increased demand will accompany the building up of storage.

A serious effort will be made to standardize lubricating oils and simplify war department specifications for greasing its motorized equipment. Both Army officers and the Defense Commission experts recognize that the service of supply cannot be encumbered by transporting many different types of gas and lubricating oils and attain the speed deemed essential to modern motorized forces.

Catalytic Hydrogenation Provides Low Cost AVIATION GASOLINE

By E. V. Murphree and F. T. Barr

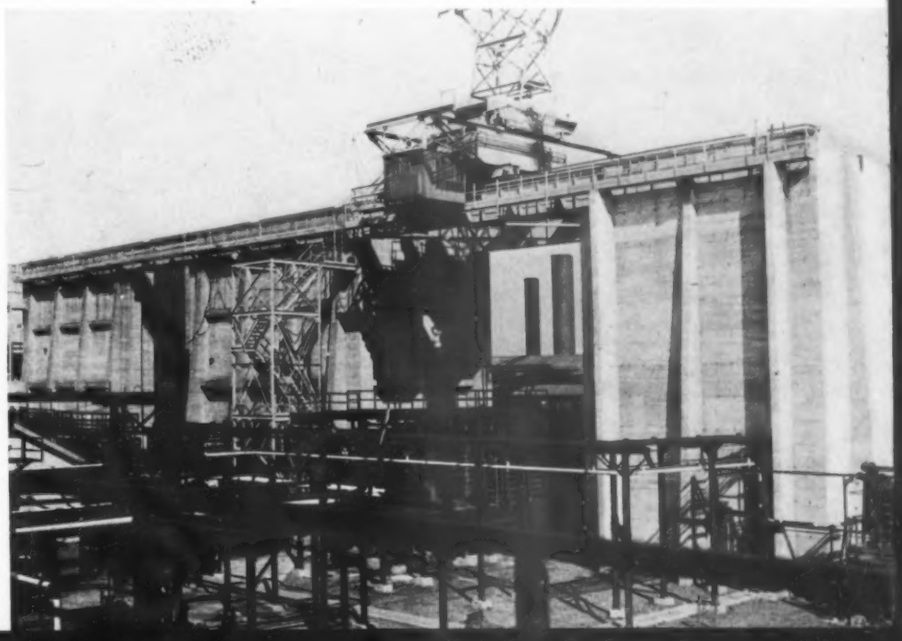
Standard Oil Development Co. — Esso Laboratories, Standard Oil Development Co.

COMMERCIAL production of a variety of petroleum products by hydrogenation has now been well established. The high pressure process has been applied in the manufacture of aviation and motor fuels, lubricating oils, kerosenes and solvents. Commercial hydrogenation has been practiced at refineries located at Baton Rouge, Louisiana; Bayway, New Jersey; Port Arthur, Texas; Richmond, California; and Whiting, Indiana. Abroad plants hydrogenating petroleum have operated at Abadan, Iran; Pernis, The Netherlands; Livorno and Bari, Italy; and Aruba, N. W. I.

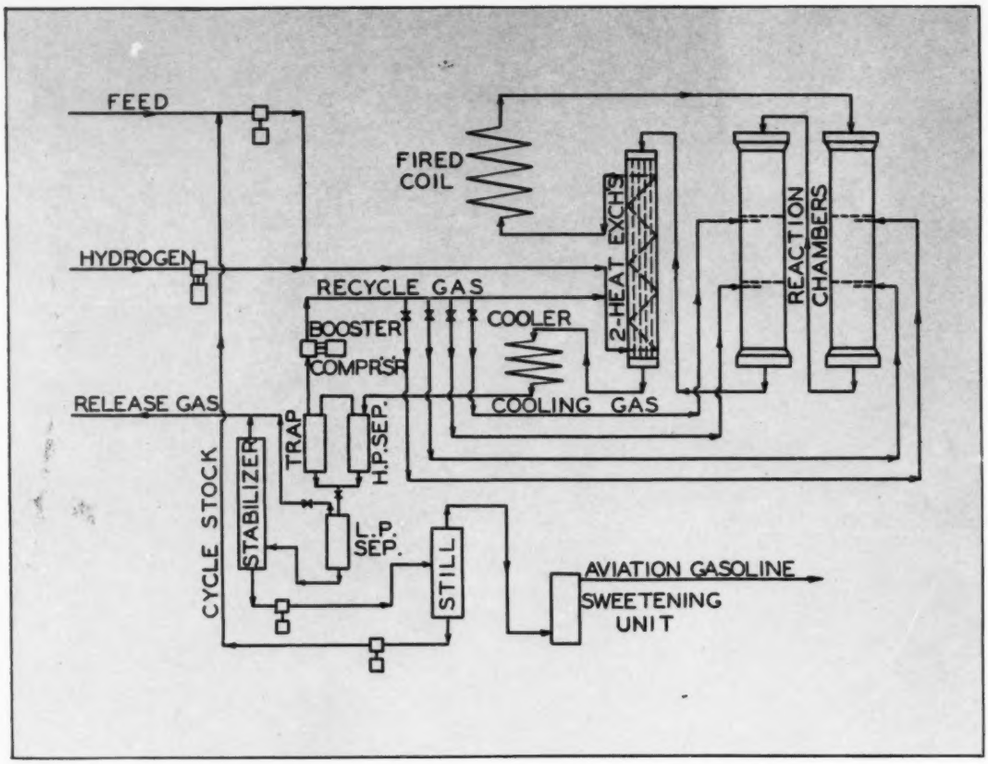
Coal hydrogenation operations and the products directly obtained therefrom differ from those secured by petroleum hydrogenation as described in this paper. Hydrogenation of coal may be carried out, however, to give intermediate hydrocarbon oils similar to the petroleum fractions described as feed stocks herein. These intermediate fractions require further hydrogenation to produce engine fuels. The overall cost for coal hydrogenation is, of course, of a higher order of magnitude than for comparable petroleum hydrogenation operations.

Of the various applications of hydrogenation, the manufacture of fuels—motor, aviation, Diesel and blendings agents—is of particular interest, because of the large requirements for these products and because of their particular utility at the present time. Hydrogenation has been adapted to the manufacture of fuels for internal combustion engines as follows:

(1) High octane number aviation gasoline from kerosene and gas oil fractions.
(2) Aviation blending agents by saturation of branched chain polymers.
(3) Motor fuels from cracked or virgin gas oils.
(4) High-grade Diesel fuels from low-quality gas oils.
(5) High flash safety fuels of high octane number.
(6) Refined (or "hydrofined") gasolines of low sulfur and high stability from high sulfur, unstable naphthas.



Above, north section of the Baton Rouge hydrogenation plant with compressor house in foreground, converter stalls in right background. Right, close up view of the converter stalls.

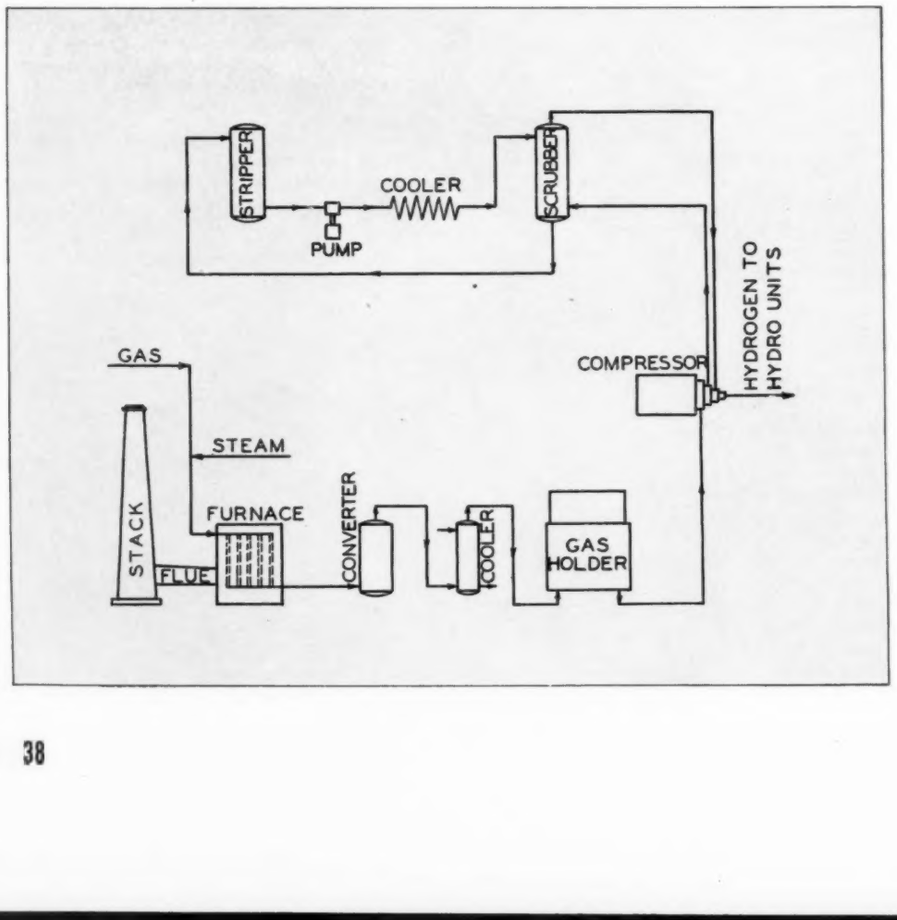


Flow plan of the hydrogenation section.

This article will be concerned only with the production of fuels by hydrogenation and will cover in detail only the first four of the above items. No commercial application of hydrofining has been made and the use of safety fuels by the aircraft industry is yet in the development stage. The other options listed above are established processes.

The hydrogenation process has already been described to WORLD PETROLEUM readers (Brown and Gohr, "Production of Aviation Fuels by Pressure Hydrogenation", Annual Refinery Issue, page 49, 1937). For convenience of the reader there are given herewith self-explanatory flow diagrams of the hydrogen-producing process and the hydrogenation plant. Flexibility of the hydrogenation process is such that all the above applications may be carried out in the same equipment. Different catalyst and operating conditions to suit the process are the only changes required.

Flow plan of the hydrogen producing unit.



Hydrogen is produced from natural or refinery gas by reactions exemplified by the chemical equation

$$CH_4+H_2O=CO+3H_2$$

which takes place in the reformer furnace, and

$$CO+H_2O=CO_2+H_2$$

which occurs in the converter. The CO_2 (carbon dioxide) is removed from the hydrogen by an alkaline scrubbing agent, and the purified gas, ordinarily about 95 percent hydrogen, is compressed to 200 atms. (about 3,000 lbs.) for charging to the hydrogenation unit.

Oil feed and recycled hydrogen are charged to the high pressure unit by means of high pressure feed pumps and recycle gas booster compressors. The oil-hydrogen mixture is conducted through appropriate heat transfer equipment and furnaces for obtaining desired temperature conditions and is then passed through catalyst contained in the high pressure reactor. The progress of the hydrogenation reaction, which involves the evolution of a considerable amount of heat, is controlled by maintaining the proper temperatures through introduction of cold hydrogen or "recycle" gas, at a number of points in the reactor. The oil-gas mixture is then cooled and separated at high pressure, the gas being returned for recycling and the oil sent to the product handling equipment.

Aviation gasoline is manufactured from low-grade virgin kerosene fractions using a catalyst developed to give high octane naphtha. The hydrogenated material boiling too high for inclusion in aviation gasoline may be continuously recycled so that all the fresh feed is ultimately converted into aviation naphtha and light gases. Operation can be carried out to give 50-75 percent conversion per pass and yields of 80-95 percent on feed.

Besides inducing the addition of hydrogen, the catalyst used in this application of hydrogenation possesses the ability to split the relatively large kerosene molecules into the smaller hydrocarbons suitable for inclusion in aviation gasoline. The catalyst, moreover, rearranges such molecules as would otherwise give low octane number, that is, the long straight-chain or slightly branched hydrocarbons, to produce saturated, bunched molecules of the type which show desirable anti-knock properties.

Hydrogenation will not produce high octane gasoline from all feed stocks. A variety of stocks which are suitable is available, however. Such stocks are generally high in naphthenic constituents and to some extent in aromatics. A highly aromatic feed is not undesirable so far as the characteristics of the products are concerned, but during the hydrogenation process the aromatic constituents are changed largely to saturated cyclic compounds and a high (by American standards) amount of hydrogen is required. Aviation fuel specifications are such that they are not easily met by thermally cracked

gasolines. Consequently the great bulk of aviation fuels have heretofore been prepared by distillation of selected crudes. Although hydrogenation feed stocks must also be selected, their availability is by no means as limited. Consequently, hydrogenation provides a commercial means of producing additional quantities of aviation gasoline and at relatively low cost. Other catalytic processes for making aviation gasoline, such as catalytic cracking and catalytic reforming, have recently been developed. The relative economic position of the various processes depends largely on the particular situation involved.

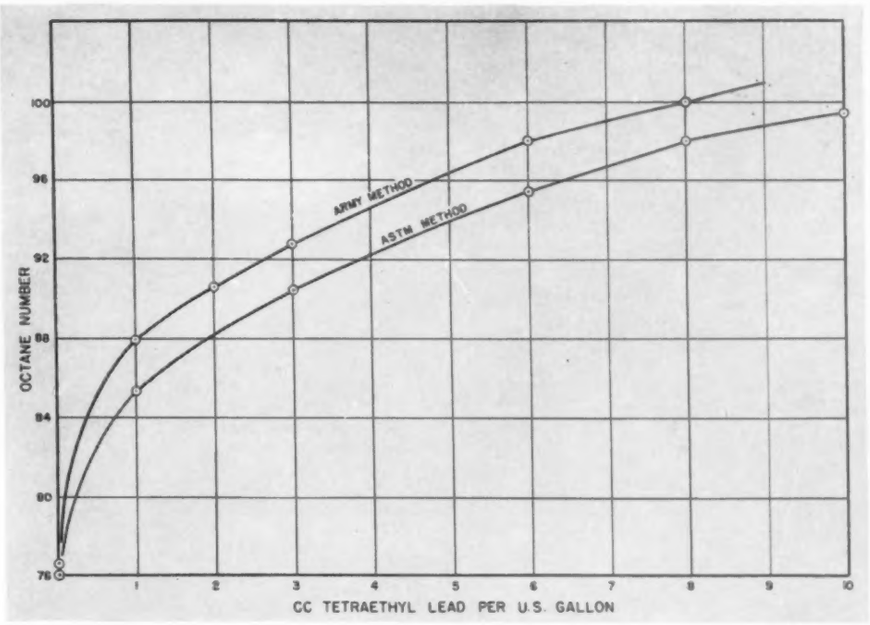
TABLE I.

Feed and Product Inspections for Aviation Naphtha Production by Recycle Hydrogenation of a Virgin Kerosene from Venezuelan Crude

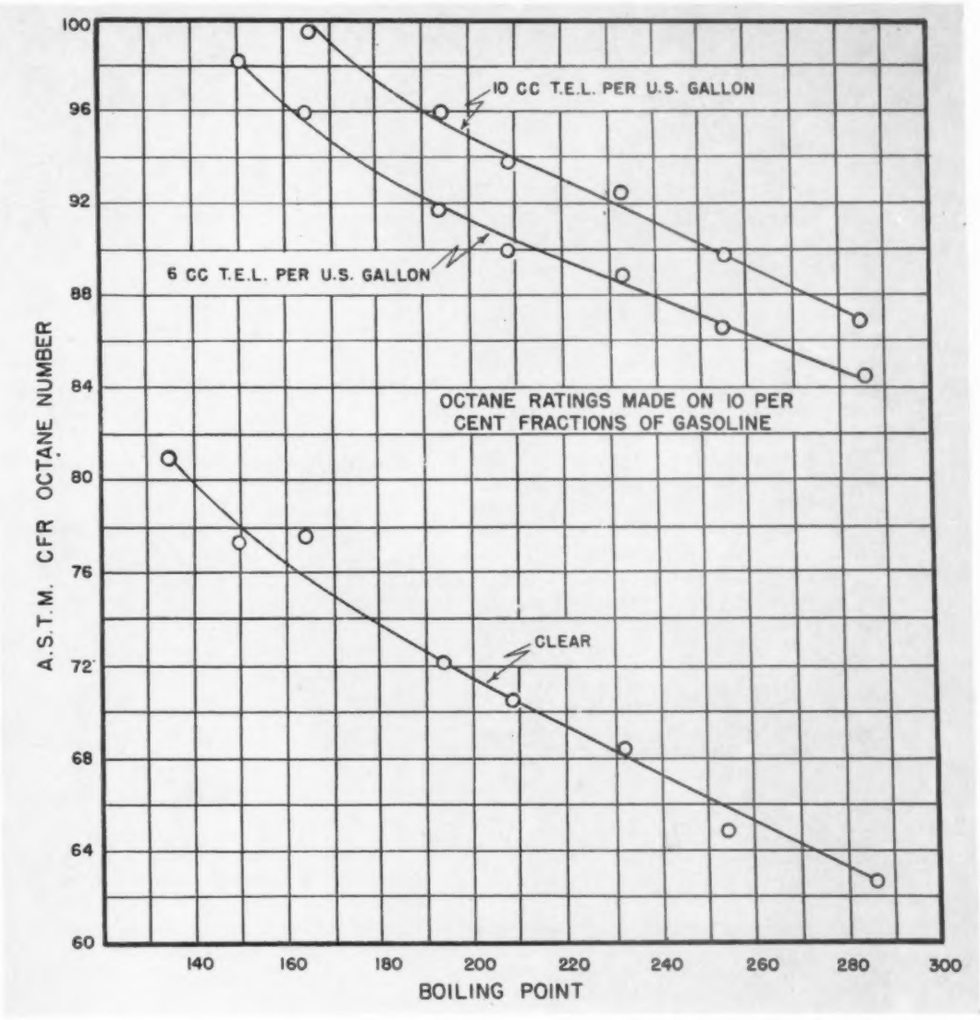
FEED	
Gravity, deg. A. P. I.	33.4
Aniline Point, deg. F.	131
Sulfur, percent	0.161
Color, Saybolt	10
Neutralization No. (Mg. KOH/gal. oil)	1.49
Ash, percent	.0008
Pour Point, deg. F.	Below -25
Tag Flash, deg. F.	135
Distillation	
Initial, deg. F.	360
10 percent	392
50 percent	444
90 percent	521
Final, deg. F.	572
AVIATION NAPHTHA	
Gravity, deg. A. P. I.	65.4
Color, Saybolt	+28
Aniline Point, deg. F.	131
Sulfur, percent	0.005
Doctor	Passes
Cu Dish Corrosion	Passes
Cu Dish Gum, Mg./100cc.	2
Glass Dish Gum	1
Army Accelerated Gum	2
Bromine No., g./100 g. oil	1
Acid Heat, ASTM, deg. F.	2
Breakdown Time, Hrs.	+24
Reid Vapor Pressure, lbs.	6.8
Octane No., ASTM	76.4
Distillation	
Initial, deg. F.	113
Percent @ 158 deg. F.	21.5
167 deg. F.	29.5
203 deg. F.	58.5
212 deg. F.	66.0
Final, deg. F.	282
Recovery, percent	98.0
Sum of 10+50 percent. dist. temp.	343
Freezing Point, deg. F.	Below -76 deg. F.

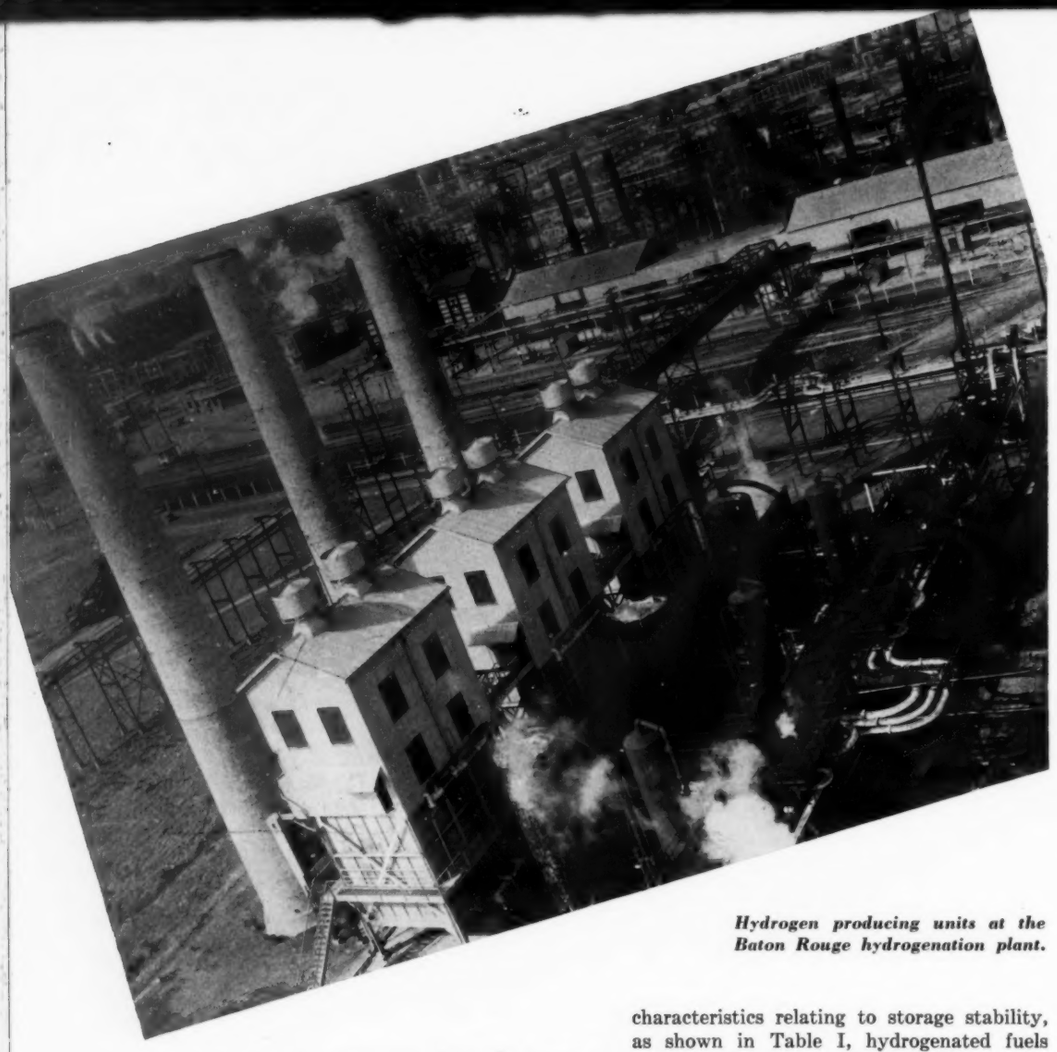
The properties of a typical feed stock and the aviation gasoline commercially produced therefrom are shown in Table I. This feed showed by analysis a composition of about 52 percent naphthenes, 41 percent paraffins and six percent aromatics. The octane number of the hydrogenated product is higher than available in the best natural naphthas obtainable on a reasonably large scale for aviation fuels (72-75 ASTM), and the hydrogenated naphtha has a lead susceptibility at least as good, as is shown in Table II. On this account hydrogenated naphthas serve as a superior base stock in the preparation of 100 octane number fuels, and high octane numbers can be obtained by simple lead addition. The octane number and lead susceptibility of hydrogenated naphthas show up well when rated by methods other than the ASTM, as is seen from the chart which shows octane number vs. lead content on a sample tested by the U. S. Army Air Corps method of determination as well as the ASTM. Preliminary testing of hydrogenated naphthas in supercharged engines also shows them to be of high anti-knock quality.

ASTM octane number and lead susceptibility ratings have been determined for



Above, increase in octane number on addition of tetraethyl lead to hydrogenated aviation gasoline. Below, ASTM octane number versus boiling range for hydrogenated aviation gasoline.





Hydrogen producing units at the Baton Rouge hydrogenation plant.

narrow cuts of hydrogenated aviation naphtha. Data showing the relation of boiling range to octane number are plotted on the chart. These indicate that the highest anti-knock constituents are contained in the low boiling fractions. The presence of branched chain and naphthenic hydrocarbons is indicated by the octane number of the fractions boiling in the n-hexane range (77 ASTM at the 160 deg. F. boiling point), which is considerably higher than that of n-hexane (35 ASTM). Octane number of the lowest boiling fraction is not shown since this boils largely in the range of isopentane (93 deg. F.) and presents difficulty in the determination of octane number. In blends with a standard reference fuel of 65 octane number the light fraction shows clear octane number blending values of about 90 ASTM.

TABLE II.

Tetraethyl Lead Susceptibility of Hydrogenated and Natural Aviation Fuels

	A.S.T.M. Octane Number	
	Hydrogenated Aviation Fuel	Natural Aviation Fuel
Cc. Lead/Gal.		
Clear	76.4	74.1
3	90.5	88.6
6	95.2	93.2
10	98.7	97.0

The exceptional stability under storage which is typical of hydrogenated aviation naphthas is indicated by the low gum and acid heat determinations. In these and other characteristics relating to storage stability, as shown in Table I, hydrogenated fuels resemble the best virgin distillates. The sulfur contents of hydrogenated aviation naphthas are lower than aviation gasoline specifications, the sulfur in the feed stock being almost completely converted to hydrogen sulfide in the process, with the result that only a caustic wash or light sweetening is required to finish the product.

TABLE III.

Inspections of Hydrogenated Dimer and Hydrogenated Codimer

	Hydrogenated Dimer	Hydrogenated Codimer
Gravity, deg. A.P.I.	70.9	67.6
Color, Saybolt	+30	+30
Copper Dish Gum, mgs./100 cc.	0.9	0.5
Copper Dish Corrosion	Pass	Pass
Doctor	Pass	Pass
Percent Sulfur	0.004	0.006
Acid Heat, deg. F.	2	1
Bromine No., g/100 g.	3	1
Breakdown Time, Hrs.	+24	+24
A.S.T.M.-C.F.R. Octane No.	99	96.5
Reid Vapor Pressure @ 100 deg. F., Lbs.	2.8	2.8
A.S.T.M. Distillation		
Initial, deg. F.	178	161
10 percent	207	213
30 percent	211	222
50 percent	212	224
70 percent	213	227
90 percent	216	231
95 percent	223	234
Final, deg. F.	249	243
Recover, percent	98.0	98.0

The hydrocarbon gases produced are also of interest. The butane fraction is primarily isobutane and constitutes a potential source of isobutane for alkylation. Likewise, the pentane fraction contains little n-pentane and can be employed to advantage in premium grade aviation fuels.

High Octane Aviation Blending Agents are currently produced by several of the major oil companies in the United States and abroad by high pressure hydrogenation. Both commercial isooctane and "hydrocodimer" are produced for this purpose. Isooctane results from hydrogenation of the dimer produced in the polymerization of isobutylene, while hydrocodimer is manufactured by hydrogenation of the dimer product in cross-polymerization of isobutylene with normal butylene. Under well-controlled conditions, yields of hydrogenated dimer or codimer amount to 100 percent or more by volume on hydrogenation feed.

These blending agents are highly stable, similar to hydrogenated aviation naphthas. The octane number of commercial isooctane produced by hydrogenation will in general be somewhat higher than that of the hydro codimer. In view of the consumption of only half the amount of isobutylene in the manufacture of hydro-codimer, however, use of the latter allows the production of roughly twice the amount of blending agent, since isobutylene is ordinarily the starting material available in smallest amounts. Typical inspections of hydrogenated dimer and codimer are shown in Table III. The octane number of the isooctane runs about 98-100 ASTM and of the hydrocodimer from 3-5 points lower.

TABLE IV.

Properties of Super-Aviation Fuel Prepared by Blending Isopentane with Hydrogenated Dimer and Adding 3.0 cc. of Lead per U. S. Gallon.

A.P.I. Gravity	73.5
Color, Saybolt (unleaded)	+30
Copper Dish Corrosion	Passes
Copper Dish Gum, Mg./100 cc.	Nil
Doctor Test	Passes
A.S.T.M. Acid Heat, deg. F.	2
Sulfur, percent	0.015
Reid Vapor Pressure, Lbs./Sq. In.	5.8
Army Accelerated Gum, Mg.	2
A.S.T.M. Octane No.	97 +3.0cc.*
Distillation—	
Initial B. P., deg. F.	108
Percent Distillate +Loss@	
167 deg. F.	12.5
212 deg. F.	50.0
230 deg. F.	97.5
Final B. P., deg. F.	239

*97 O. N. primary reference fuel +3.0 cc. lead per gallon.

Aviation blending agent of 92 ASTM octane number can be prepared by alkylation. It will be noted that this octane number is somewhat lower than that of hydrocodimer. In many large refineries an excess of olefines exists, so that it is advantageous to polymerize the isobutylene with normal butylenes and use the excess olefines for alkylation with whatever isobutane is available. Thus, alkylation and hydrogenation may often be economically complementary in the production of high octane aviation blending agents.

By using hydrogenated aviation naphthas as base stocks and hydrogenated polymers as blending agents, super fuels with octane numbers well over 100 Army rating can be obtained with the addition of lead, as shown on page 41. Inasmuch as the hydrogenated dimers consist of closely related chemical compounds of similar boiling points, they do not possess the volatility characteristics ordinarily required of aviation gasoline. This may be corrected by adjusting the volatility of the base gasoline or, more easily, by using

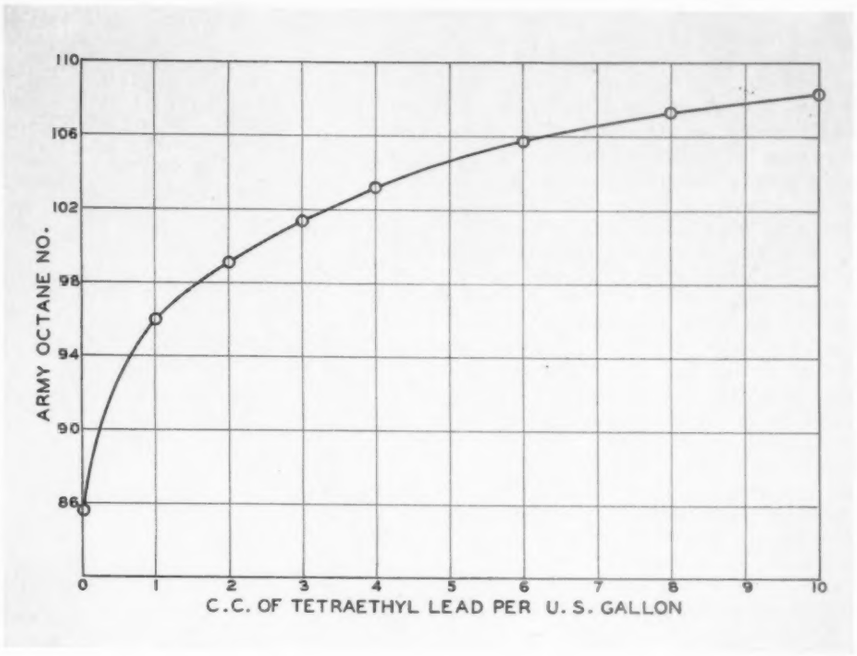
as blending agent a mixture of the hydrogenated dimer with isopentane—which may be available from hydrogenation operations themselves. The distillation characteristics and other properties of a blend prepared in this way are shown in Table IV.

TABLE V.

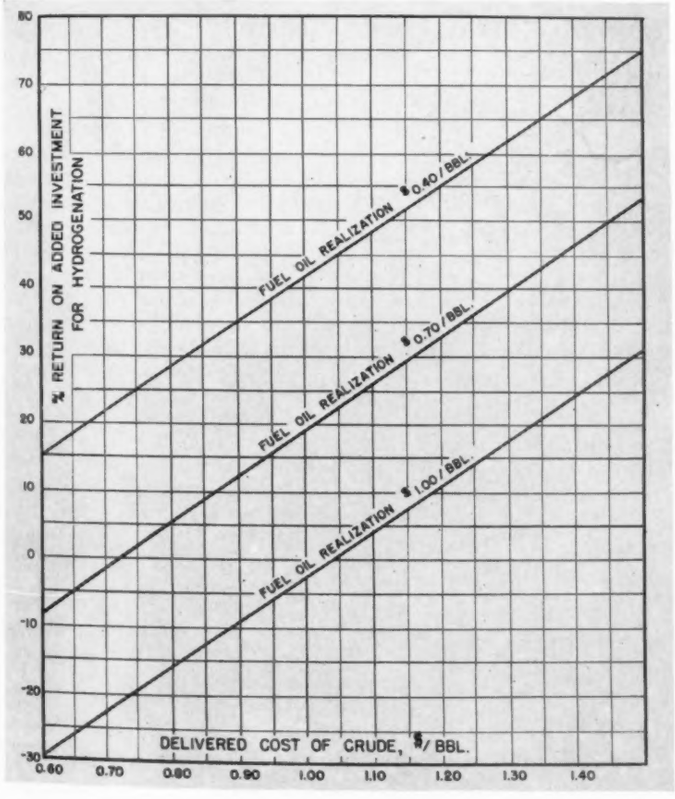
Feed and Product Inspections of Motor Gasolines by Once-Through Hydrogenation.

	Cycle Gas Oil	Coastal Virgin G.O.	Venezuelan Light Virgin G.O.	East Texas Virgin Gas Oil
Feed Stock				
A. P. I. Gravity	26.1	25.4	36.1	36.5
Aniline Point, deg. F.	81	90	133	157
Distillation, deg. F.				
Initial B. P.	211	257	326	408
50 percent over	465	543	425	520
Final B. P.	572	700	533	641
Sulfur, percent	0.060	0.270	0.090	0.131
Hydrogenated Motor Gasoline				
A. P. I. Gravity	53.4	56.8	58.2	60.4
Color, Saybolt	+30	+30	+30	+30
Copper Dish Gum, Mg./100 cc.	6.0	3.5	3.9	2.5
A. S. T. M. Acid Heat, deg. F.	2	3	2	1
Sulfur, percent	0.002	0.004	0.003	0.004
A. S. T. M. Octane No.				
Clear	73.2	72.0	73.2	63.5
+1 cc. Lead	83.2	81.2	81.7	77.5
Reid Vapor Pressure, lbs./sq. in.	8.1	10.8	10.9	8.6
Distillation, Percent over @				
158 deg. F	12.5	14.0	19.0	11.5
212 deg.F.	31.0	31.0	34.5	30.5
Final B. P., deg. F.	401	410	388	390
Gas Oil				
A. P. I. Gravity	30.5	31.7	36.1	43.7
Color, Saybolt	+20	+20	+30	+25
Aniline Point, deg. F.	114	137	142	179
Distillation, deg. F.				
Initial B. P.	374	309	385	408
50 percent over	451	483	430	490
Final B. P.	545	652	512	587

High Octane Safety Fuels are prepared by hydrogenation of polymers in very much the same way as are the aviation blending agents. High flash safety fuels have arisen from a need for aviation fuels with vapor pressures sufficiently low to minimize the possibility of flashing into flame through accidental ignition. In order to effect this, flash points of 100 deg. F. or higher are required. This specification is met by hydrogenating a trimer, or condensation of three butylene molecules. Similar boiling range materials could, of course, be distilled from natural naphthas, but there are available no natural products which approach the high octane desired for this purpose. Hydrogenated trimers have octane numbers almost as high as the hydrogenated dimer, that from polymerization of isobutylene alone showing 99-100 ASTM and those from cross-polymerization of isobutylene with normal butylene 92-96 ASTM octane number.



Increase in army octane number on addition of tetraethyl lead to 100 octane number base gasoline composed of hydropentane, hydrocodimer and hydrogenated aviation fuel.



Percent return on added investment for hydrogenation over thermal cracking as a function of crude and fuel oil prices.

TABLE VI.

Cracking vs. Hydrogenation of West Texas Crude

Type Operation	Thermal Cracking	Hydrogenation
Overall Yields on Crude		
Gasoline, volume percent	41.3	54.5
Heating Oil, volume percent	28.7	37.8
Heavy Fuel Oil, volume percent	26.4	9.4*
Gas, weight percent	3.5*	1.8*
Runs per 10,000 B/D of Gasoline plus 6940 B/D of Heating Oil		
Crude Consumed, B/D.	24,200	18,350
Fuel Oil Produced, B/D.	6,400	.....
Total Feed to Hydrogenation.	.....	10,850
Inspections—		
Gasoline		
Reid Vapor Pressure, Lbs./sq. in.	10.0	10.0
Distillation, percent over @		
158 deg. F.	20.7	21.2
212 deg. F.	43.1	43.5
257 deg. F.	67.9	66.6
A.S.T.M. Octane No.	69.6	66.0
C.F.R.-Research (1939) Octane No.	74.3	68.4
cc. Lead to 81.5 C.F.R.R. (1939) O. N.	1.5	1.5
Heating Oil		
Gravity, deg. A. P. I.	32.2	35.8
Fuel Oil		
Gravity, deg. A.P.I.	9.0	.....
Viscosity, Saybolt Furol sec. @ 122 deg. F.	130	.....

*Consumed to meet operating fuel requirements.

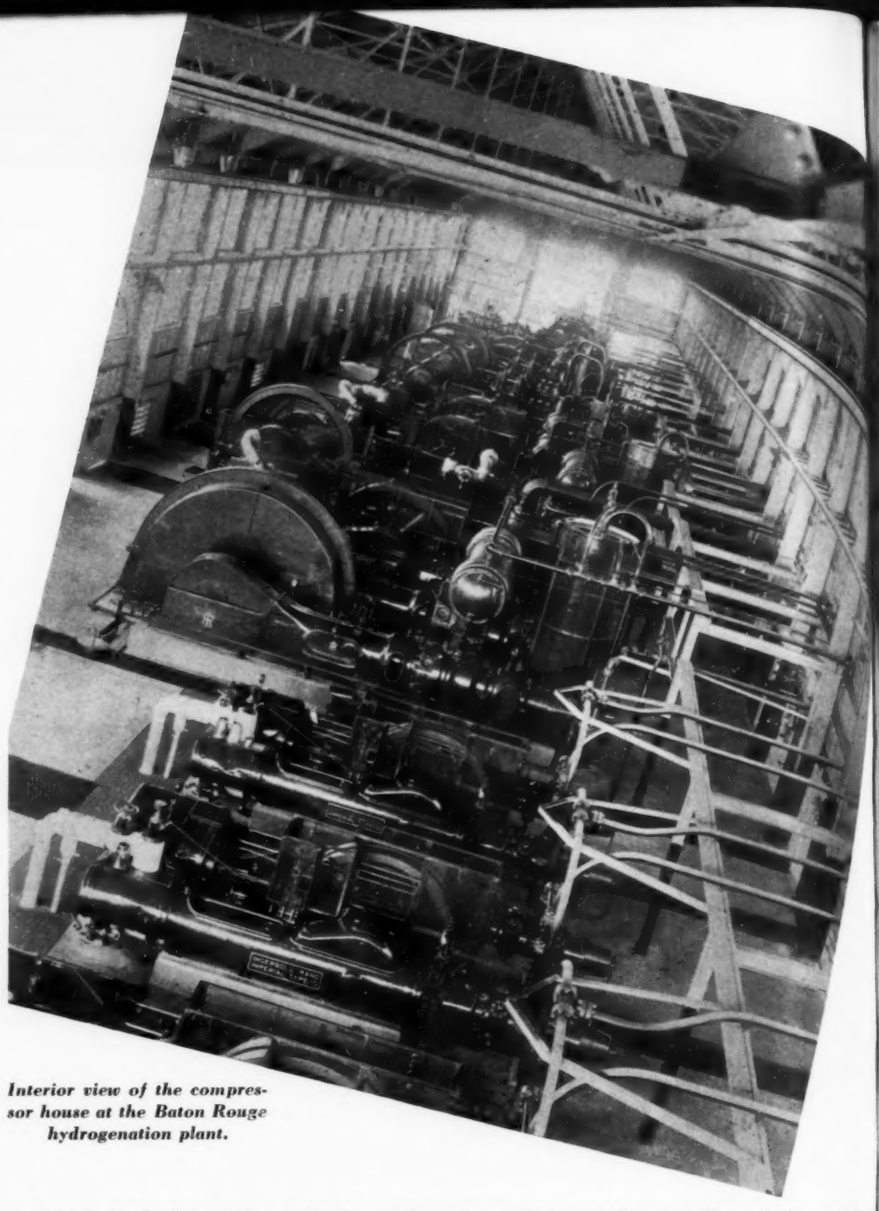
Motor Gasolines do not require the special characteristics of hydrogenation products so distinctively as do aviation gasolines.

The high degree of stability desired for aviation fuels is of less consequence in motor fuels and unsaturated hydrocarbons are no less suitable than the completely saturated molecule obtained by hydrogenation. The higher yields, good lead susceptibility and lower sulfur product remain as advantage for the operation. In Table V are given inspections of feed stocks and motor gasolines produced therefrom by once-through hydrogenation. Conversions were 60 to 80 percent by volume on feed, and the total liquid yield (gasoline plus gas oil bottoms) was 105-110 percent. While bottoms might be recycled to ultimate yield of gasoline as in the aviation gasoline production, their value for use as distillate heating oils, Diesel fuels, etc. may often be greater than as recycle hydro feed. The same types of feed stock are desirable for motor gasoline production as for aviation gasoline production. However, since lower octane number is ordinarily satisfactory, the variety of feeds available for motor fuel production by hydrogenation is considerably increased.

The fundamental economic advantage of the hydrogenation process over other methods is that the production of a given quantity of refined products requires less crude. This results from the better yield obtained because of lower gas make, and the absence of coke formation or production of heavy bottoms which must be disposed of as fuel. Since, economically, the crude saving must be sufficient to pay for the added cost of manufacturing the product by hydrogenation compared with other means of producing the same material, hydrogenation is more attractive the greater the spread between crude cost and heavy fuel value. The upper limit of the latter is established by competition with coal so that the ultimate economic position of hydrogenation may be said to depend on the cost and availability of crude.

Because of the potentially large application if used for the manufacture of motor fuel, economic study of a process on such a basis is of most interest. Comparisons of hydrogenation plus thermal cracking with cracking only have been published (Russell, Gohr, and Voorhies, J. Inst. Petroleum Tech., 21, 347 (1935). These showed a definite advantage to hydrogenation at sufficiently high crude price. More recently similar comparison has been made taking into account the production of distillate heating oils as well as motor gasoline. Set up in this way hydrogenation, accompanied by the usual distillation processes and a small amount of naphtha reforming, can be used without the necessity of bringing in any thermal cracking. In Table VI a comparison of yields and products obtained by hydrogenation and by thermal cracking, based on the production from West Texas crude of about 40 gal. of heating oil for every 60 gal. of gasoline, is shown.

The table shows the extent to which hydrogenation saves crude. In this particular case the yield of gasoline and heating oil from 100 gal. of crude is increased from 70 by thermal cracking to 92.3 gal. by hydrogenation. The economic effect of these relations is indicated by combining the operating cost debit for hydrogenation with the crude credit and fuel debit, and expressing the resulting net saving (or loss) as percent of the added investment for hydrogenation over that for cracking. Carrying out such calculation for various delivered crude prices and fuel realizations, and including depreciation and other overheads at appropriate rates, results in the relation shown on page 41. It will be observed from this chart that if a five-year payout above depreciation is necessary to make the investment of money for a hydrogenation plant attractive, a spread of roughly 30c. per barrel between crude and fuel oil is required. During the first six months of 1939, the most recent period during which conditions might be thought normal, the posted price plus pipeline charges on West Texas crude delivered in the Gulf Coast was $1.075 per barrel. At the same time fuel oil value at the refinery was about $ .75 per barrel. With this price structure hydrogenation shows about 20 percent return.



Interior view of the compressor house at the Baton Rouge hydrogenation plant.

Diesel Fuels are produced by once-through hydrogenation of low quality gas oils. Gasoline production is secondary, representing only a small proportion of the overall yield and conversion to 80-90 percent Diesel fuel is possible. High-quality Diesel fuels require high cetane numbers, low sulfur content, and low pour point. Hydrogenation is well adapted to obtaining these characteristics, since it improves the paraffinicity, hydro gas oils showing Diesel indices of 60-70, and removes nearly all the sulfur from the feed stock. To produce the low pour point desired, advantage is taken of the low pour of an asphaltic base feed stock.

The present demands for high quality Diesel fuels are met by fractionation from selected crudes. If, however, these requirements increase so that manufacture from lower grade stock is necessary, hydrogenation will be competitive with solvent extraction methods. While hydrogenation has a greater investment and higher operating cost than solvent extraction, it generally gives somewhat better yields of the paraffinic material and is less dependent on the character of the feed stock. In addition, the by-products of hydrogenation are gasoline and kerosene, whereas in extraction a low value cracking stock is made.

Technological Trends Modified by WAR CONDITIONS

Year's New Processes Illustrate Alterations in Trend of Refining Technique Arising from World Shift to War Economy.

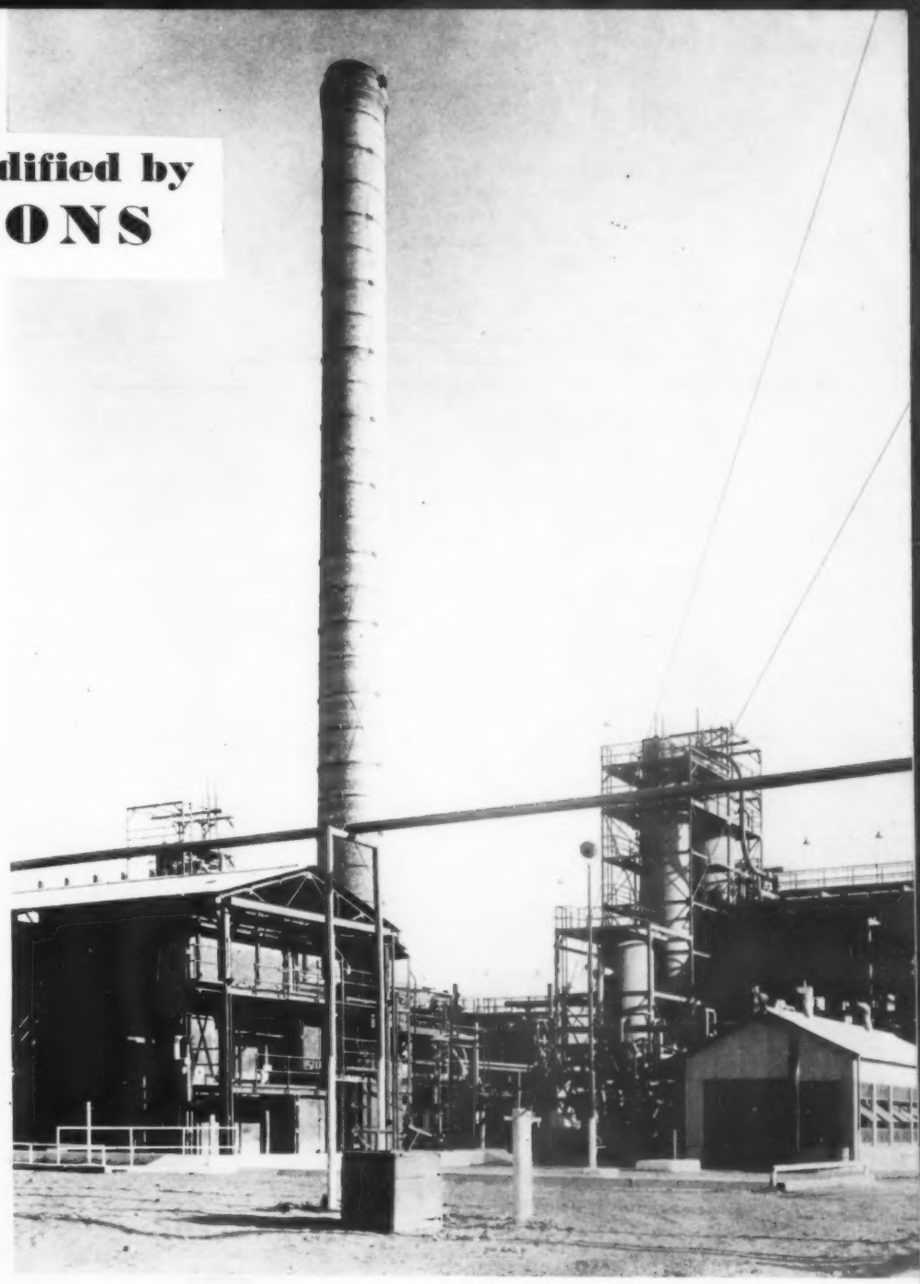
DURING the past year the petroleum refining industry has remained under the influence of several major trends.

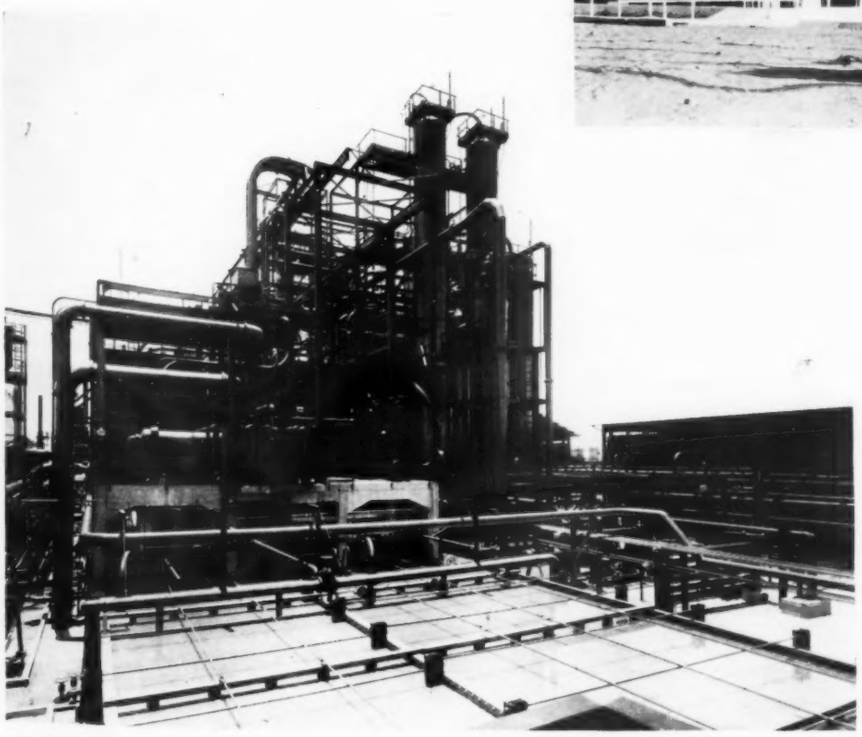
One of these influences, of course, is the state of war that has been existing in the old world, which has obstructed the normal flow of trade in petroleum products, and has forced radical alterations in the petroleum economics of many nations.

Aside from dislocation of trade, the refinery industry has been called upon to reorient some of its technology to meet the military situation. In the United States this reorientation has taken the form of greater emphasis on high grade fuel for military aviation.

Defense requirements have brought to the fore another exigency, which it seems that the petroleum refining industry is in the best position to meet, namely, a scarcity of aromatic hydrocarbons that serve as a basis for making high explosives such as trinitrotoluol (T. N. T.). Heretofore these indespensable military requisites have been obtained from coal tar, but this source of supply is now seen to be too limited. No actual production of military toluol has yet been started in this country, but a number of refineries are known to be actively preparing for this emergency.

Right: naphtha-gas reversion unit of the Phillips Petroleum Company at Borger, Texas. Below, a general view of part of the Port Arthur Texas plant looking northwest.





T. N. T.

Raw material for high explosives may be produced from petroleum in two ways, one of which is to fractionate out the aromatic hydrocarbons that occur naturally in some crudes. Borneo, Roumanian and some Russian crudes, for instance, are particularly rich in these constituents. Although some domestic refineries are marketing special solvents containing much aromatics, in the United States this natural resource is limited, and for military purposes recourse must be had to molecular rearrangement of petroleum distillates.

This is currently being done, not for the purpose of obtaining military toluol, but as one expression of the growing urge to put more octanes into gasoline. When severely cracked (high temperatures and pressures) naphtha molecules, for instance, will be extensively fragmented, and the fragments will tend to reunite in the form of cyclic or ring (aromatic) compounds, of which toluol is one. These cyclic and ring compounds have good antiknock quality and hence aromatization and cyclicization of distillates is already a part of current refinery technology. To put this technology to military use will require control of the process so as to favor toluol production and suppress the formation of unwanted aromatics. From recent patent literature it appears that this may be accomplished by a selective catalyst such as a mixture of chromium and vanadium trioxide on an alumina base. With a suitable hydrocarbon charge (C_6 to C_{12}) and proper operating conditions yields of toluol may be as much as 30 percent on a once through basis. There has also been some mention of a chromium-alumina catalyst for producing aromatics by dehydrogenating and polymerizing propane and butane. At the present writing no details are available.

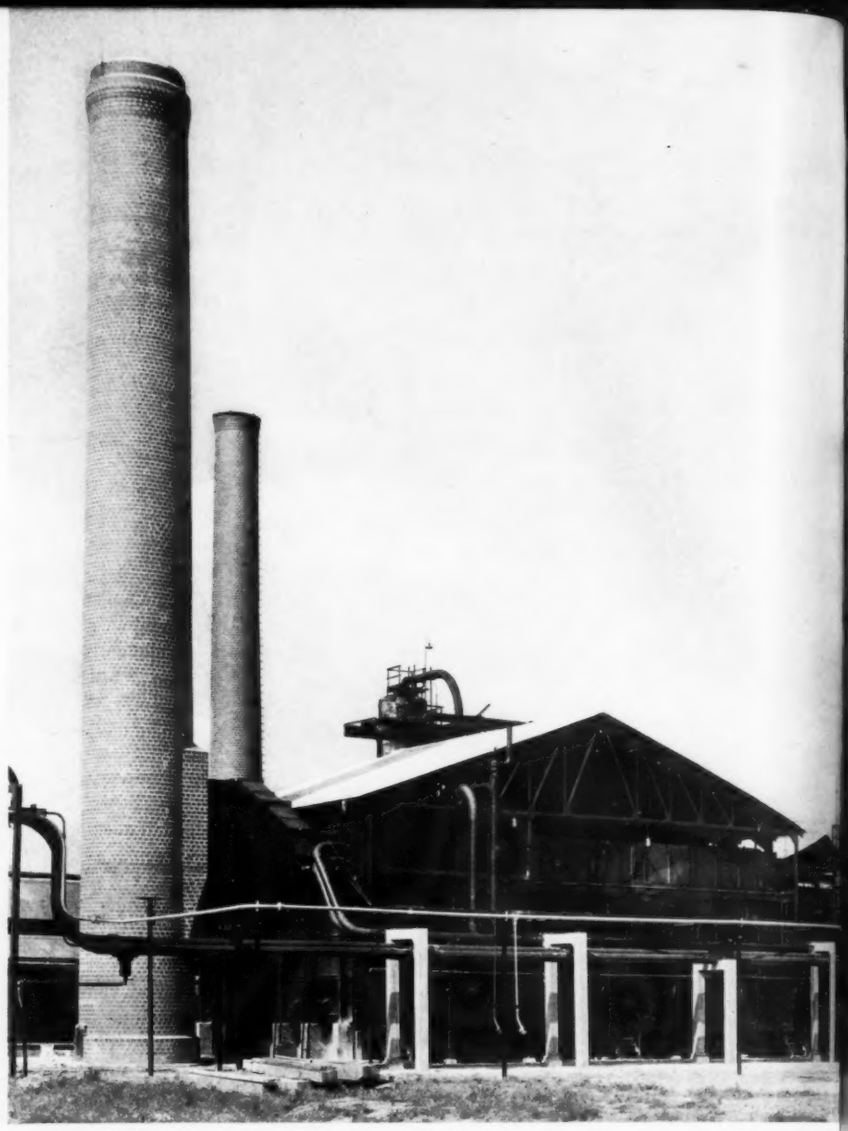
WAR

There are various signs that the technology of oil refining in the belligerent countries has been profoundly affected by war conditions especially in those countries where native oil supplies are limited and cannot now be supplemented by imports. The Germans for instance, have been driven to make use of every possible expedient to overcome their handicap in the matter of military fuel. For one thing, they are said to have proved that by suitable engine design and operation their light Messerschmidt bombing airplanes can match or even outfly British pursuit planes with gasoline having an octane number no higher than 73.

In the matter of lubricants they claim to have perfected the synthesis of better and more uniform lubricating oils from Fischer-Tropsch products. This is said to be accomplished by polymerization of long chains and condensation of long chains to aromatics, to give lubricants of fairly definite compositions.

Again, driven as they are by necessity, they are said to have at last made a success of producing fatty acids from mineral or artificial petroleums. For instance, by controlled oxidation of high melting paraffins they are producing these acids in 35 to 40 percent yields, which is a great help to their soap industry. When the war is over we shall doubtless find they have made noticeable contributions not only to the practical chemistry of petroleum but also to collateral and related industries that supplement petroleum. All possible hydrogenizable materials such as tars, etc., are being relentlessly exploited; liquefied and compressed gases are freeing much military gasoline, and the use of producer gas from coke, etc., in civilian motor transport has become a fine art.

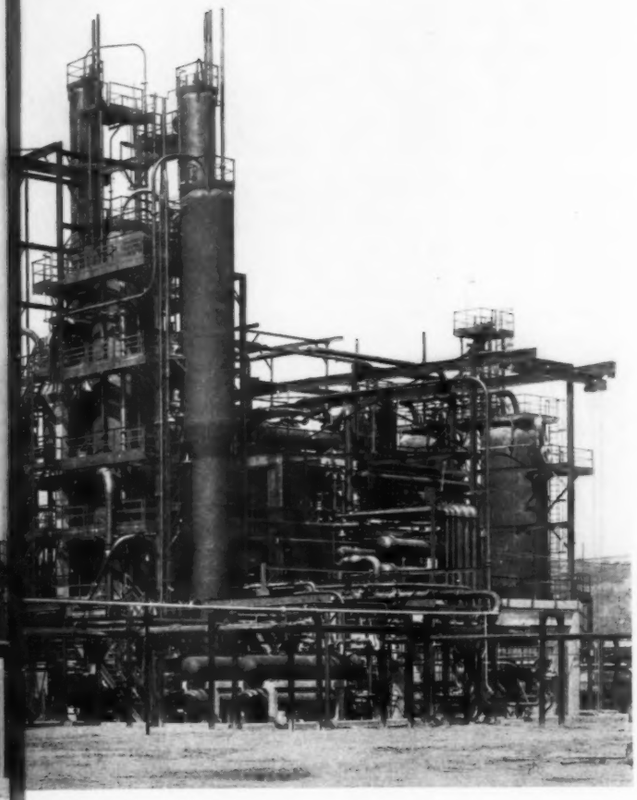
In the United States the oil refining industry is feeling the spur of an increasing domestic consumption of motor fuel on the one hand, and a demand for higher quality motor and aviation fuel on the other hand. The joint effect of these forces is requiring the oil refiners to enlarge correspondingly their capacities, and to alter their processes to meet quality requirements. Aside from that, competitive conditions have continued to impose the necessity of reducing costs. The combined result of all this is to force a large section of the industry to sustain a considerable program of new construction and modernization which it is estimated is costing around $200,000,000 annually.



As we said, much of this modernization is dictated by the quality *motif*. The average octane number of regular gasoline is rising at the rate of three to four points a year. The refinery technologists have reacted to this trend in numerous directions. One of these directions is toward an enlargement of thermal cracking operations applied to crudes and gas oils, and reforming operations on naphthas which are manipulated so as to yield blending stocks of higher octane rating. As a result, within the last year the production of cracked gasolines for the first time exceeded the combined production of straight-run and natural gasolines. The quality *motif* is also responsible for various new or improved processes which will receive notice farther along.

INTEGRATION

While the technology of thermal cracking operations has not lately experienced any very radical changes, it has nevertheless had the benefit of much improved mechanical detail. As a part of the modernization process, the tendency is toward larger units for the sake of greater economy; oil refineries are becoming larger and tend to become fewer by consolidation of small into bigger plants. In the construction of these bigger plants more attention is being paid to "integration". An integrated modern combination thermal cracking plant will comprise crude topping and cracking units, debutanizer, stabilizer, hydrogen sulphide-removal unit, reforming and catalytic polymerization units, caustic wash unit, etc. These various units are knit together and integrated by an extensive system of control instruments. This instrumental control system is one of the most remarkable and least publicized developments of modern petroleum refining technology. In a great refinery, operations must proceed smoothly and practically automatically, from the tank farm to the shipping platform. No unit must perform its functions at



In Cincinnati, Ohio; a naphtha polyform unit of the Gulf Oil Corporation. This process is fully described on page 56.

either a faster or a slower rate than its fellow members of the system, and to secure this coordination as many as 100 or more regulating instruments, each automatically responsive to actions of the others, are installed at strategic points. Much of the economy and not a little of the safety of refinery operation is due to this continuing progress in instrumentation.

While thermal cracking still supplies most of the cracked gasoline, catalytic cracking has definitely entered the commercial picture in the form of the Houdry process, which was practically unheard of two years ago but is now represented by 17 plants with a total case charge capacity of 195,200 bbl. a day; 15 of these plants, with capacities totalling 187,865 bbl. are in the United States. Accounts of the operations of these plants indicate that the process is functioning smoothly and within economic limits. Within the past year various Houdry plants which started as catalytic cracking installations with catalytic treating units for the gasoline produced, have added catalytic reforming units for the catalytic polymerization of butenes in the liquid phase.

The existing Houdry cracking units appear to be maintaining the reputation of the process for uniformly good yields of gasoline with relatively high octane number (78-80) from any kind of crude stock. At least one Houdry unit is making aviation gasoline base with an A. S. T. M. octane number of 80, which requires only 30-35 percent of alkylate or other high octane equivalent for making 100 octane (Army method) fuel. The significance of this development is the reduced amount of alkylate or equivalent required.

CATALYTIC CRACKING

Mention of the Houdry process brings up the immense subject of catalysts in the oil refining industry. This is a field of research and development which is perhaps attracting more interest than any other single branch of the business. An examination of the literature suggests that if there is not already a catalyst for every purpose there are enough workers engaged in the search to bring about that result in a few years.

The Houdry system itself contemplates a wide variety of catalysts. There is a catalyst for cracking reduced crudes, another for treating the produced gasoline and another for polymerizing the cracked gases; these are said to be more or less of the same basic material which has been physically modified to suit particular circumstances, but in some cases used interchangeably. A special Houdry catalyst has been developed for desulfuring purposes, but no commercial use seems to be made of it.

CATALYTIC RESEARCH

The main hope of the catalyst researchers is to find a catalyst that will not only produce a high yield of gasoline from any stock, but will function continuously, i.e., without stopping for regenerating. Some claims have been made that this goal has been achieved but it has not yet been fully commercialized. The reason for this search for a continuously functioning cracking catalyst is not hard to see. In the Houdry process, for instance, the cycle includes a 10-minute period of cracking, followed by a purging period, a 10-minute regenerating period and a repurging period that in all consume the equivalent of 20 minutes, i.e., cracking goes on for approximately a third of the time. The installation cost of a Houdry unit is therefore nearly double that of an equivalent thermal unit. Obviously, if regeneration and subsidiary operations could be dispensed with, installation costs might be greatly reduced. Even so, the catalytic process has evidently demonstrated its commercial feasibility for large scale operations.

That great expectations are being entertained in the catalyst field is indicated by the announcement that the Houdry Process Corporation has established a laboratory exclusively devoted to catalysis research; this institution cost $700,000 to build and equip and will employ a personnel of 110 technologists and operators. One fruit of this project is said to be a new synthetic cracking catalyst that will produce yield increases of the order of 15 to 20 percent of an even better quality of gasoline. While the new catalyst will not function indefinitely without regeneration, it is said to be purged more easily and quickly than the old one, and its operating cycle is longer. A further attribute of the new Houdry cracking catalyst is that the gases issuing from the cracking cases contain a larger than ordinary proportion of iso-butane than of normal butane, the ratio of the two being about 85:15 in favor of the iso hydrocarbon.

100-OCTANE

The general problem of obtaining a larger supply of iso-butane is itself in the forefront of interest, because it is one of the key materials for the preparation of super-octane gasoline. In the present state of the art the manufacture of 100 octane number gasoline requires the addition of iso-octane or its equivalent to a suitable gasoline base. Not so long ago the chief source of iso-octane was cracked refinery gas containing C_3 and C_4 olefins, which could be thermally polymerized to octylenes that, by hydrogenation, become iso-octanes. The supply of C_3 and C_4 olefins in refinery gases, however, is limited. One method of increasing or extending this supply was to crack thermally the butanes contained in these gases and in natural gas. But butane is resistant to thermal cracking; the yield is small and much of the cracked product is liable to loss on account of the high cracking temperature. Still, the handicap of a limited

supply of butenes has been partly overcome by recent developments in alkylation processes, whereby olefins can be combined with iso-butane to form iso-octane with or without an intermediate hydrogenation. This makes a given supply of butenes go twice as far. But there remained the handicap of a limited supply of iso-butane as well as of butenes.

So the problem of an enlarged supply of 100 octane gasoline has appeared to be largely dependent on obtaining more butene and iso-butene. Several answers have been found or proposed. One is use of a catalyst like the new Houdry catalyst mentioned above, which furnishes cracked refinery gases greatly enriched in iso-butene. It is said that a plant for producing isobutane from normal butene, using an aluminum halide catalyst is under construction. A great desideratum is also to increase the supply of C_3 and C_4 olefins by catalytically cracking propane and normal butane, of which large quantities are obtainable from natural gas, provided such treatment gives larger yields than thermal cracking.

A long step in this direction appears to have been taken in a new Universal Oil Products process by Egloff and his associates who have developed a chromium oxide catalyst on an alumina base which is applied to the conversion of gaseous paraffins (except methane) from any source into the corresponding olefins. The yield of olefins is said to be of the order of 85 to 95 percent, figured on the original charge of paraffins. The process is therefore offered as a substitute for the method of cracking thermally the gases which gives a yield of not more than 15 percent of butene on butane. For the economic success of the thermal process the butane used cannot be valued higher than 1.615 cents per gallon. There are no side reactions in this catalytic process; i. e. formation of propene from butane is suppressed. The catalyst has a long life and its selectivity is constant. The process may be conducted so that a mixture of butane and butene is obtained suitable for direct polymerization and hydrogenization to produce iso-octane.

Another process of obtaining high-octane bases which has received some attention is to treat desulfurized and depropanized gases with a nickel catalyst. As in the case of thermal polymerization of a mixture of olefins, the product of the nickel catalyst is a mixture of octylenes that may require the further step of catalytic hydrogenation.

NEOHEXANE

Once a mixture of C_3 and C_4 material of the proper character has been obtained, it may be converted into iso-octane or an equivalent mixture of high octane value by one of several methods: by thermal polymerization and hydrogenation, or by catalytic polymerization (U. O. P.), or by one or another form of the sulfuric acid process, preferably the cold acid process, which seems to have outclassed all other processes in this field. By the cold sulphuric acid process now being operated by several major companies, together with the prospect offered by the new U. O. P. process mentioned above, it appears that the probable future demand for iso-octane or equivalent can readily be met, particularly if the production of Houdry cracked gasoline or the like, which requires a minimum of high-octane supplements, should be expanded. But it is a fact that iso-octane is only one of a number of aviation fuel ingredients. One of the newest and most interesting of these is called neohexane, which has been introduced by Phillips Petroleum Company. This is produced by reacting iso-butane with ethylene under the conditions of thermal alkylation. The strong point of neo-hexane is its very high octane number (100 A.S.T.M.) and its volatility; iso-octane is deficient in the latter property and hence has to be supplemented by light ends to produce the required Reid vapor pressure. Incidentally, the case of neohexane illustrates the profound effect of molecular structure on the anti-knock quality of a hydrocarbon. Normal hexane, which is a straight chain hydrocarbon, is notoriously deficient in octane quality. Neohexane has the same number of carbon and hydrogen atoms, but these are arranged in branch or side chains so that the molecule is more or less globular in form. It is this difference in molecular arrangement that makes the difference in anti-knock quality.

It should be mentioned in this connection that thermal alkylation of the type used to produce neohexane appears to have a somewhat wide promise. In contrast with catalytic alkylation, where only iso-butane reacts, in thermal alkylation normal butane and propane also reacts with olefins to produce alkylates. The thermal process succeeds easiest with ethylene, but less so with higher olefins.

While iso-octane or its equivalent holds the spotlight in the play for more octanes, gasolines of high if not the highest quality are also being produced by other means. Prominent among these is simple catalytic (U. O. P.) polymerization of the olefins of cracked refinery gases. The polymer gasoline thus produced is used for blending purposes. There is some talk of reviving low pressure or vapor phase cracking as a source of octanes, and it need not be overlooked that skillful reforming of gasolines and naphthas may turn out a product with up to 90 octane number.

One recent process of reforming comes in for mention. It bears the trade name of "polyforming", and has a modification that is called gas reversion. In principle this process aims to unite two operations that heretofore have been carried out separately. In the one of these separate operations the attempt is made to subject cracked refinery gases, mostly propane and butanes, to a thermal cracking to convert them into hydrocarbons boiling within the gasoline range. But these gases require high cracking temperatures that also destroy more or less of the cracked products. Hence it has been necessary to shorten the cracking period and to employ a large recycle ratio. In the other separate operation naphtha is thermally reformed to break up large molecules into smaller ones, and to effect more or less of cyclization, aromatization and polymerization that helps the octane rating of the product.

In the combination or polyform process the cracked refinery gases and the naphtha are reformed in one operation. The gases are first liquefied under pressure, mixed with the naphtha and sent through the reforming furnace under appropriate operating conditions; this is polyforming. In gas reversion the gases are given a preliminary heat treatment before joining the hot naphtha stream. After that, the joint product is fractionated as usual.

The new technological point of this process is that the gases and the naphtha cooperate. The presence of the gases helps to suppress coking of the naphtha, and the naphtha helps the gases to dissociate into recoverable products. The net result is shown to be both a larger yield of gasoline and a better anti-knock quality than would be obtained from the separate operations, and a separate gas treating plant is dispensed with. The polyform process is discussed at length elsewhere in this issue.

While the octane race with its adjuncts of catalyzation, dehydrogenation, polymerization, hydrogenation, isomerization, alkylation, aromatization and cyclicization has provided much copy for the petroleum press, there is continuing activity on all other fronts of refining technology. Some of this activity has been producing notable results in what is, relatively, a minor field. This is the utilization of petroleum products and by-products as raw materials for industrial chemical synthesis. Of chief interest at the present time are aromatic hydrocarbons suitable for the manufacture of high explosives, and for rubber substitutes. Butadiene has already become the parent of buna rubber, and now the Esso laboratories have introduced butyl rubber, which is composed of simple olefins with a small percentage of diolefins; if it becomes feasible for butyl rubber to compete with natural rubber there will be a greater demand than ever for petroleum unsaturates.

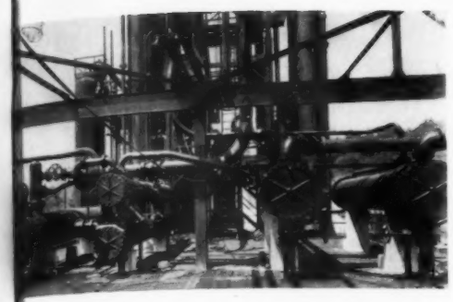
This division of the refining business is more remarkable for its diversity than for its volume, which is quite small in comparison with gasoline. Still, synthetic petroleum products, too numerous to be mentioned here, are already well established in the markets in the form of alcohols, ethers, solvents, insecticides and dozens more. Diethylene glycol, synthetic glycerine, soap bases and the like are quoted in respectable tonnages. The list grows almost daily, and still some petroleum by-products await possible customers, as for example the mercaptans that are being extracted from sour gasolines by new processes.

SULFUR REMOVAL

In the preparation of all petroleum products the final essential step is purification. Chief among the substances that have to be got rid of is sulfur.

The classic method of removing sulfur from gasoline is the Doctor treatment with lead plumbite; this method has well known limitations. It does not remove all forms of noxious sulfur, and this defect of the Doctor treatment has called forth a number of processes that more nearly meet the situation.

Among the latest of sulfur-removing pro-



Heat exchangers at the Cincinnati naphtha polyform unit of the Gulf Oil Corporation.

cedures is one that has received the name of "solutizer" process; this process uses caustic potash mixed with potassium isobutyrate to accomplish what the Doctor process cannot do—remove all forms of sulfur, including mercaptans. The solutizer process appears to have quite perceptible advantages in the following particulars; the sulfur content of the treated gasoline is reduced to quite negligible proportions; the susceptibility of the gasoline to tetraethyl lead is notably improved; in contrast with the Doctor method, the octane rating of the gasoline in the clear is somewhat improved, and treating losses are reduced. Nevertheless, the Doctor process is still holding on; it is even being improved, and the time and expense attending its use are being reduced by application of new ideas. It is likely to disappear in time, however, and give place to the simpler and more thorough reversible contact processes.

Complete removal of all forms of sulfur—hydrogen sulfide, mercaptans, mono-sulfides and di-sulfides is also being effected by a catalytic desulfuring process in which vapor of naphtha at 700 deg.-750 deg. F. are passed over a bauxite catalyst; marked reduction occurs in the tetraethyl lead requirement, and the 60-octane number naphtha becomes a blending agent.

Other new means of removing sulfur include washing with a solution of potassium triphosphate to absorb hydrogen sulfide; this reagent can be regenerated and used again. In some cases aviation gasolines are treated with bauxite in vapor phase at 750 deg. F. In cases where a simple caustic wash will suffice it has been found practicable to use milk of lime instead of the more expensive caustic soda.

Of late, interest in the problems of sulfur removal has been sharpened by a more general realization that the presence of even small amounts of sulfur has an unfavorable effect on the lead susceptibility of gasolines, and that the expense of treatment may be more than compensated by the raising of the product into a higher price bracket.

DECOLORIZING

Like the classic Doctor method of sweetening sour gasolines the classic clay treatment for improvement of color is feeling the pressure of new products and methods. Bauxite has become a competitor of fuller's earth by reason of greater decolorizing power and other advantages, but, as is also observed with the obsolescent Doctor process, the absolescent fuller's earth process is holding on by virtue of some belated improvements. The clay material is being offered to the refiner in an improved form; and particularly, new and more convenient means of regenerating the spent clay have been invented; the regeneration process may now be conducted so that some active carbon will be left on the clay particles to improve the decolorizing power.

The number of decolorizing agents and processes that have been offered to the oil refining industry is already large and is increasing almost daily. Mention may be made of a proposition to improve the color of cracked distillates by an acid wash followed by washing with a solution of caustic soda dissolved in methanol.

A contribution to the decolorizing of lubricating oils is to raise the duty of filter clays by first treating the lube oil with propane to precipitate petroleum resins.

LUBRICANTS

In the matter of the solvent refining of lubricating oils there has been relatively little recent expansion, probably due to the fact that the existing plants can meet the demand. Among the various processes of solvent extraction that have become established the order of preference, as indicated by number and capacity of the installations, appears to be: furfural—Duosol—phenol—sulfur dioxide benzol.

Although industrial expansion in this branch has slowed down temporarily, the researchers are still very busy testing out all possible kinds of selective solvents. Much attention has been attracted to mixed solvents among which may be mentioned mixed normal-propyl ketone and methyl normal-butyl ketone.

Among proposals for handling the distillation of lube stocks may be mentioned a process in which the oil is distilled under a high vacuum, with arrangements such that the vaporized molecules would have to travel only a very short path. Another proposition is the Couborough or "carrier" distillation process in which heavy oils are distilled in the presence of the vapor of some lighter substance like kerosene or light gas oil. This has been emphasized as a means of separating asphalt.

A relatively new direction in the compounding of lubricating oils is the use of additives or substances that will confer on the lubricant properties not present in the original material. Among such agents are polybutenes (made from iso-butene) which are employed to improve the viscosity index and confer stringiness and body on the oil.

Such substances are useful as additions to asphalts for confering on them both a higher softening point, more penetration and less cracking tendency; they also improve the coating qualities of paraffin waxes. Prominent among these additive agents is the trademarked substances "Exanol".

Refinery technology falls broadly into two general categories; the category of process technology and the category of equipment technology. In the foregoing part of this review various trends in process technology have been brought under notice and a number of the newer processes are discussed in detail elsewhere in this issue.

EQUIPMENT

In the equipment technology of petroleum refining a principal trend has been (as previously mentioned) toward large scale operations for the sake of economies that may thus be realized; another trend, also mentioned, is toward extensive instrumental control of integrated operations.

The trend toward large scale operations has produced cracking stills and fractionating towers of previously unheard of dimensions. The high pressures required in some refining or synthetic operations has made it necessary to build vessels strong enough to resist these pressures. One constructional method which has attracted some notice is to wrap sheets of metal around a cylinder until the desired thickness of wall (4-5 in.) has been built up. The completed cylinder is then supplied with ends and fittings. An advantage of this construction is greater strength at reduced cost and especially the fact that only the central cylinder need be of some resistant alloy.

The matter of resistant metals for refinery use is a large one and has been attracting a due amount of attention. It is indeed a serious matter. The raw materials of the refining industry are generally corrosive. Depreciation of metal equipment is often high and the expense of maintenance and replacement is burdensome.

No one answer has been found to the corrosion problem, due to variations in materials and circumstances. There is a general tendency to use alloy steels in all process equipment where high temperature comes into question. Where hydrogen sulfide is a major pest chromium carbide steels have been found resistant. In general some form of chromium alloy is indicated where operating temperatures will exceed 600 deg. F. Chromium-molybdenum alloy has been indicated for heater piping and fittings, with silicon - chromium - molybdenum steels for temperatures up to 1,300 deg. F. At the other end of thermal operations—the low temperatures encountered in operations that require refrigeration under high pressure—nickel steels have been recommended.

There is, however, a tendency to abandon low refrigeration in the recovery of distillate from condensate wells of the Gulf Coast, in favor of high pressure absorption in special oils.

Aside from the corrosion problem, the major concerns of the refining industry are safety, and the general matter of improving efficiency. Under the latter comes the matter of increasing fuel efficiency, which really means fuel economy. In some of the modern integrated combination cracking installations heat consumption is said to have been reduced to 200,000 British thermal units per barrel of throughput.

World's First Commercial NEO-HEXANE Produced in Phillips Plant

Gains up to 25 percent in basic power output anticipated for aircraft powered by this newly developed fuel giving U. S. Military planes performance characteristics presently unattainable in any other country.

A GREAT deal of attention has been directed lately to the octane number of gasolines. This property of a motor fuel, its ability to be used without perceptible knock, can be realized only when combined with other necessary properties of a fuel which permits it to be utilized in the most efficient manner. In view of these facts it is necessary, therefore, to evaluate a motor fuel from its overall standpoint instead of merely by its octane number.

During the past year the Phillips Petroleum Company has developed a material known as neohexane which, when combined with other ingredients, permits the manufacture of an aviation fuel that not only has the highest octane number of any heretofore commercially available gasoline, but also has the other requirements for a balanced aviation fuel. The development and production of this new product, neohexane, is unique from a great many standpoints. The material was originally developed in the laboratory, tested in a pilot plant, and now is being produced in a large scale plant. An interesting fact is that the materials produced by all of these methods have virtually the same properties.

Neohexane is chemically known as 2,2-dimethylbutane. This hydrocarbon has been known to scientists for a number of years but only as a synthetic laboratory product made by difficult and expensive methods and was never before available in quantities of more than a quart or two at a time. The first accumulation, anywhere in the world, of quantities larger than this was the storage in connection with the Phillips pilot plant.

A few years ago the product commercial isooctane, which has an octane number in the low 90's, was made synthetically only in the laboratory and today is the base material in all ethylized 100 octane number aviation fuels. The development of isooctane permitted aviation fuels to be produced with a higher octane number than the 87 octane number existing at that time. Data are presented in Figure 1 to show what the trend has been in the octane number of the aviation gasolines purchased by the Air Corps over the past 10 years. A similar curve but with a lower and regular trend could be shown for the fuel used by commercial air lines. No signs of abatement in the base requirement for higher octane number fuels are apparent from these trends.

During the last few years great progress has been made in aeronautics resulting in higher air plane speeds and greater cruising distances. As a result of the improvement in octane number, as shown in Figure 1, it has been possible to develop more power per unit of engine weight as well as to secure lower fuel consumption. As an example of the benefits derived from using balanced gasolines of higher octane number, the use of 100 octane number gasoline resulted in a gain of 25 percent in the basic power output of military aircraft over the previous performance possible with 92 octane number gasoline. The advent of neohexane is expected to overcome certain limiting factors now prevailing in the path of still higher octane number fuels. It is expected that under optimum conditions the use of this new material will result in another 25 percent increase in the basic power output. In other words, the development of neohexane will permit air-craft performances not now obtainable in any other country.

In order to understand fully the part neohexane plays in the aviation gasoline industry, some of the history of the development of aviation fuels will be given.

Prior to the advent of the new synthetic gasolines (such as isooctane and neohexane) the highest quality product in general use had an octane number of less than 75. This could be increased, however, to a range from from 87 or 92 (depending on method of determining the octane number) with the addition of about 3 cc's of tetraethyl lead (TEL) per gallon. While more tetraethyl lead may be added, the increase in octane number diminishes very rapidly as greater quantities of lead are added so that it becomes uneconomical to use large quantities of lead in order to obtain higher octane number gasoline. The current high octane number aviation gasoline, usually 100 octane number, is a mixture of synthetic isoocatne and selected aviation gasoline materials together with the addition of 3 cc's of TEL.

Isooctane which is produced in commercial quantities from the C_4 hydrocarbons (butanes and butenes), is a synthetic paraffin hydrocarbon of low volatility (high boiling point). By blending commercial isooctane with selected straight run or natural gasoline of varying volatility and in suitable proportions, an aviation fuel possessing a properly balanced volatility is obtained. Although commercial isooctane has an octane number in the low 90's, it cannot be used alone as an aviation gasoline because its boiling range is too high for satisfactory operation in air-craft engines as presently designed. That is why it is necessary to blend with isooctane some straight run or natural gasoline in order to overcome this deficiency in volatility. The inclusion of these lower octane materials in the blend impairs the final octane number properties so that even with the addition of tetraethyl lead, octane numbers of more than 100 are seldom achieved.

Because of the volatility characteristics of isooctane which requires the blending of low octane number volatilizing ingredients with it, neohexane becomes a very important ingredient in the production of high octane number aviation gasoline. The volatility characteristics of neohexane are such that a perfectly balanced aviation gasoline may be manufactured by blending this material with commercial isooctane and isopentane (a very volatile high octane number ingredient obtained from natural gasoline). In this blend none of the relatively low octane number straight run or natural gasoline is required. All the ingredients of an aviation fuel so manufactured would have octane numbers of the same order as commercial isooctane, and as a result octane numbers considerably above 100 can be produced with the addition of tetraethyl lead. With the appearance of this material on the market, neohexane is the only available high octane material of moderate volatility.

The manufacture of commercial isooctane and neohexane is basically by the polymerization process, that is, where light weight hydrocarbons, usually gaseous, are converted to heavier hydrocarbons, usually liquid. Probably the most outstanding commercial development in the last few years in the petroleum industry has been in the polymerization field. The chief application of the polymerization reaction has been with refinery gasses as raw materials, although much progress has also been made with the natural gas hydrocarbons. The first large scale installation of thermal polymerization was made by Phillips Petroleum Company. Most of the polymerization plants have been installed within the last five years. Polymerization has indeed played an important role in the petroleum industry. It has extended the usefulness of other processes for the manufacture of gasoline and at the same time has been an important factor in conserving our petroleum resources. In fact, it can be said that polymerization has created for the economist a new definition for petroleum reserves.

While the process for the manufacture of

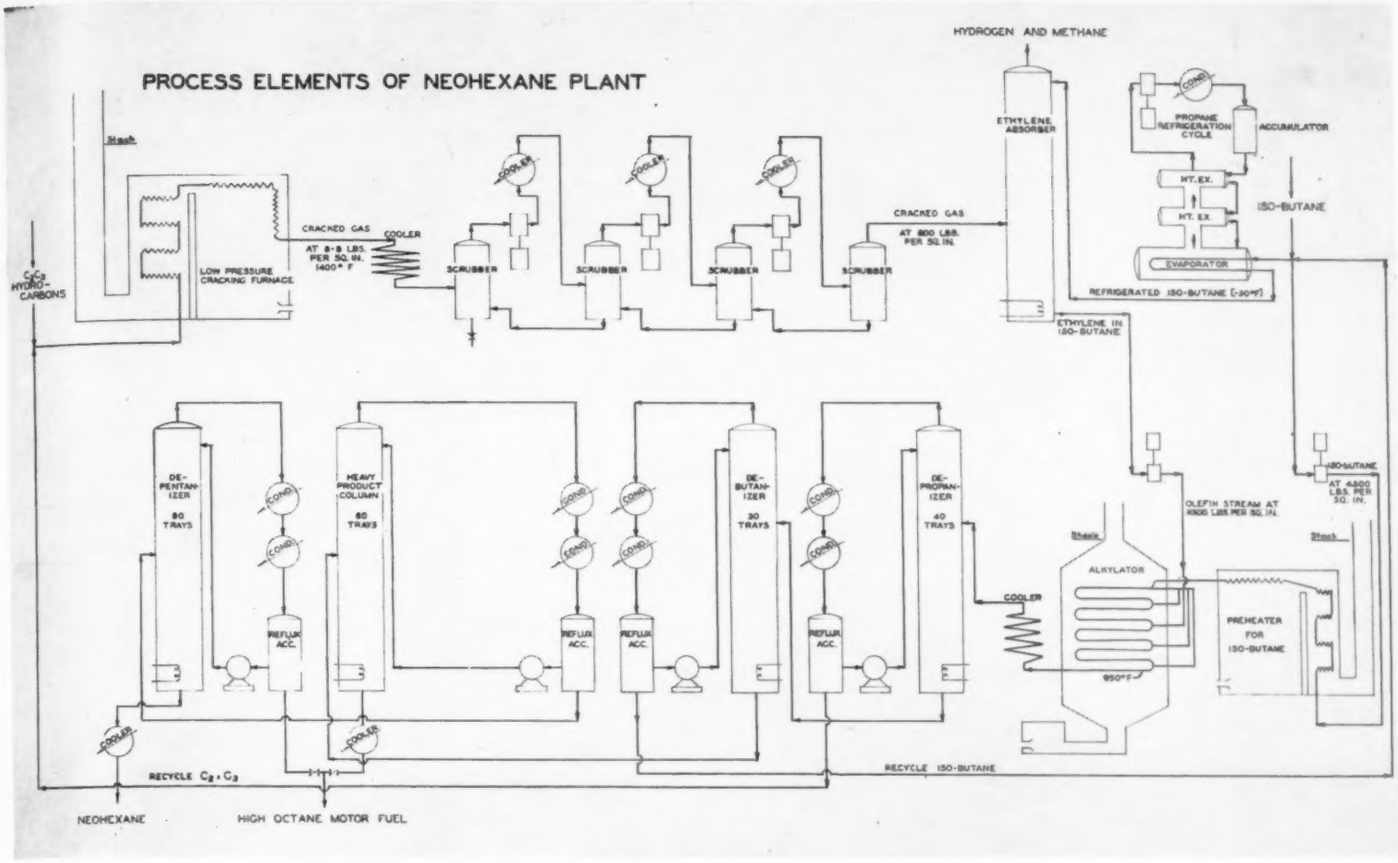


Figure 2

neohexane falls in the general category of polymerization processes, it converts gaseous hydrocarbons to liquid hydrocarbons, more specifically, however, it is known as an alkylation process and is based on a chemical reaction involving the direct union of the proverbially inert paraffins with other hydrocarbons. Until a few years ago chemists thought this reaction would not take place. The neohexane conversion of gaseous hydrocarbons to liquid hydrocarbons is effective without catalyst but is essentially a controlled chemical synthesis. The conversion is carried out in one or two stages depending on whether ethylene is available as such or must be obtained by controlled cracking.

The two stages are briefly as follows:

1. Ethane and propane are cracked to produce ethylene.
2. Ethylene plus isobutane are reacted to produce neohexane.

The process elements are shown schematically and in somewhat simplified form in Figure 2. A C_2-C_3 (ethane and propane) mixture is cracked to produce ethylene in tube furnace units. For efficient ethylene production, cracking at high temperature and low pressure is required. The temperature and pressure are approximately 1400 deg. F. and six to twelve pounds (gauge) respectively. The tube coils are of necessity constructed of a ferrous alloy with high heat resistance. The severity of the cracking is so regulated as to produce a maximum content of ethylene in the cracked gas, the cracked gas containing under these conditions only a little ethane and propane, together with hydrogen, methane, propylene and minor amounts of other constituents.

The cracking reactions for the ethane and propane in the coil are mainly the following:

(1) $C_2H_6 \rightarrow H_2 + C_2H_4$
ethane — hydrogen — ethylene

(2) $C_3H_8 \rightarrow CH_4 + C_2H_4$
propane — methane — ethylene

(3) $C_3H_8 \rightarrow H_2 + C_3H_6$
propane — hydrogen — propylene

The cracked gas, after cooling and passing through an oil scrubber to remove a trace of light carbon and tar formed in the cracking, passes to a compression system in which it is raised in three stages to a high pressure to facilitate ethylene recovery. Small quantities of aromatic oils formed in the cracking operation are condensed and removed and the ethylene is then extracted for subsequent reaction with isobutane to produce the neohexane. The extraction is accomplished in a bubble tower, the ethylene absorber, using isobutane as the absorption medium. The enriched isobutane contains virtually all the ethylene, as well as the limited amounts of the more readily extractable propylene, propane and ethane surviving the cracking. Methane and hydrogen are not absorbed and pass from the top of the absorber. Both the high absorption pressure and a degree of refrigeration are required to obtain efficient extraction. The refrigeration of the incoming isobutane is effected by a conventional propane refrigeration cycle, and additional facilities not shown, are provided to increase the efficiency with which refrigeration is utilized. The operating conditions in the ethylene absorber are: pressure, 800 lbs. per sq. in.; temperature of incoming isobutane minus 30 deg. F. The enriched isobutane contains approximately 50 percent of hydrocarbons extracted from the cracked gas.

The alkylation, or more specifically the ethylation, of isobutane by the ethylene is carried out at a pressure of 4,500 lbs., the highest pressure in commercial use for any hydrocarbon polymerization process. The temperature in the alkylation coil is maintained at 950 deg. F.

The 4,500 lbs. pressure gives efficient alkylation and virtually eliminates carbon and tar formation as operating problems, but it presented many new engineering problems to be solved. However, to consider first the conversion unit, the basic requirement is that, while isobutane is maintained at conversion temperature, the ethylene must be introduced in low concentration during reaction, more being added as it is consumed. Added in high concentration, the ethylene will polymerize, and become unavailable for undergoing union with isobutane to produce neohexane. In the plant this is accomplished by passing the isobutane stream through a tube coil at reaction temperature and introducing the enriched isobutane containing the ethylene simultaneously through several inlets distributed along the reaction coil. The isobutane is raised to 4,800 lbs. pressure by a multiple cylinder charge pump, equipped with internal cooling for the plungers, and it then passes through a tube furnace in which it is brought

to reaction temperature. The stream then passes through a reaction coil in a separate housing. The olefin feed inlets consist of small diameter tube inlets discharging into those of the removable headers so located as to give the proper reaction time interval between additions. The flow volume to each inlet is maintained at the desired rate by a flow controller operating at a pressure level necessarily slightly higher than the reaction pressure itself. The enriched isobutane stream is delivered to the inlets by a separate charge pump of the type used to charge the isobutane. Some additional heat is required, and the reaction temperature in the coil is maintained at the desired level with the assistance of hot flue gas passing upward around the tubes, the temperature being maintained at the desired level by the aid of heat from additional products of combustion.

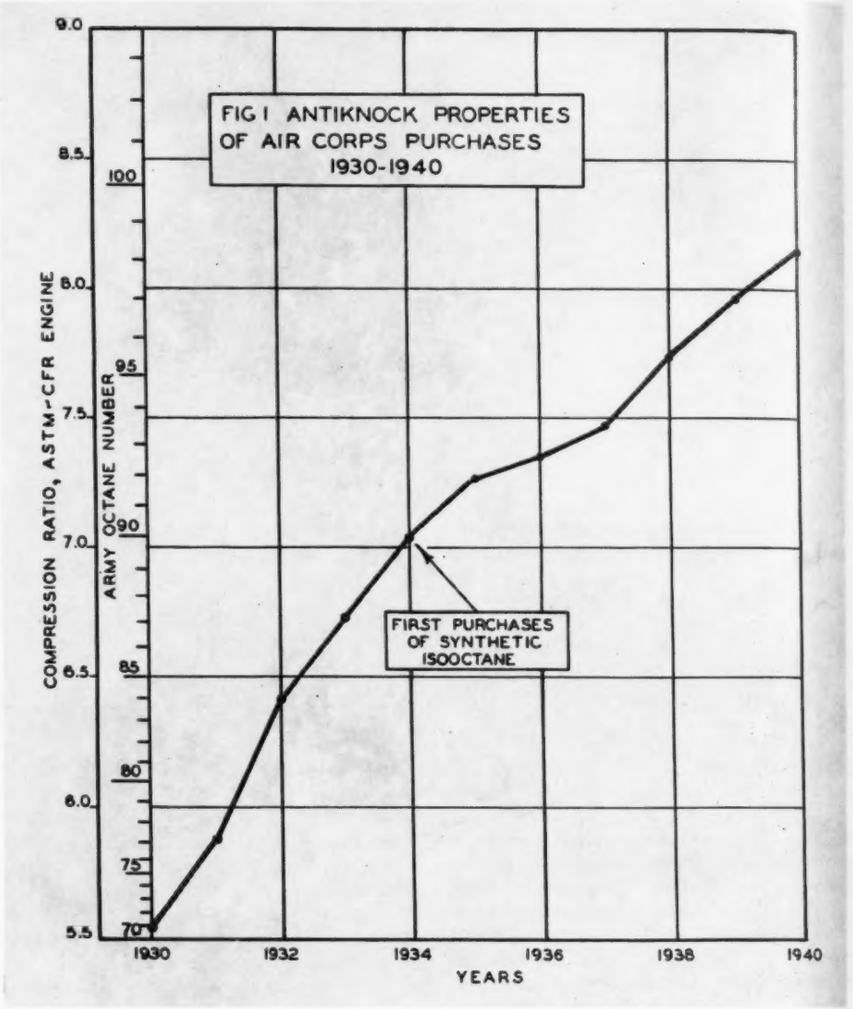
The stream discharged from the alkylation coil passes through an expansion valve, where pressure is reduced to about 800 lbs., then through waste heat boilers where the heat in the stream is used to produce steam, for use in the process and elsewhere. From the waste heat boilers the stream passes to a depropanizer column, where there is eliminated the ethane and propane surviving the original cracking and a minor amount of methane produced in the alkylation, which are returned as feed to the cracking operation. To avoid loss of isobutane to the overhead stream, some refrigeration is required for producing the reflux. This column operates with a top temperature of about 104 deg. F. under about 325 lbs. per sq. in. with a reflux ratio of 5.5 to 1. The stream then passes to the debutanizer column, where there is removed the isobutane, present in large excess which is returned to the alkylation and absorbing steps. This column operates with a top temperature of about 125 deg. F. at 100 lbs. per sq. in. The reflux ratio is about 1.5 to 1. The debutanizer kettle product is the total alkylation product, virtually all in the gasoline range, containing a small amount of pentanes and a major amount of hexanes and higher which are respectively lighter and heavier than the neohexane present.

The fractionation temperature required to isolate the neohexane is indicated by reference to the tabulation below, which also shows the boiling points of the neighboring hydrocarbons.

Isopentane	82.3	(°F.)
n-Pentane	96.8	
Neohexane	121.5	
2, 3-Dimethylbutane	136.6	
2-Methylpentane	140.4	
3-Methylpentane	145.8	
n-Hexane	155.8	

The intervals separating neohexane from its higher and lower neighbors are sufficiently great to make its isolation reasonably easy in rather pure condition.

The total alkylation product from the debutanizer kettle passes to a column to make the separation between the neohexane and the heavier material. The separation is exacting, since high purity of the neohexane is desired, so a 60 plate column is used at this point. The neohexane and lighter, produced as overhead product, pass to a virtually identical column where the lighter material is eliminated, and



neohexane is produced as the kettle product. These columns operate at low pressures, 5.5 and 14 lbs. per sq. in. respectively and with top temperatures of 124 deg. F. and 107 deg. F. The close fractionation desired calls for rather high reflux ratios, 10 to 1 or somewhat less.

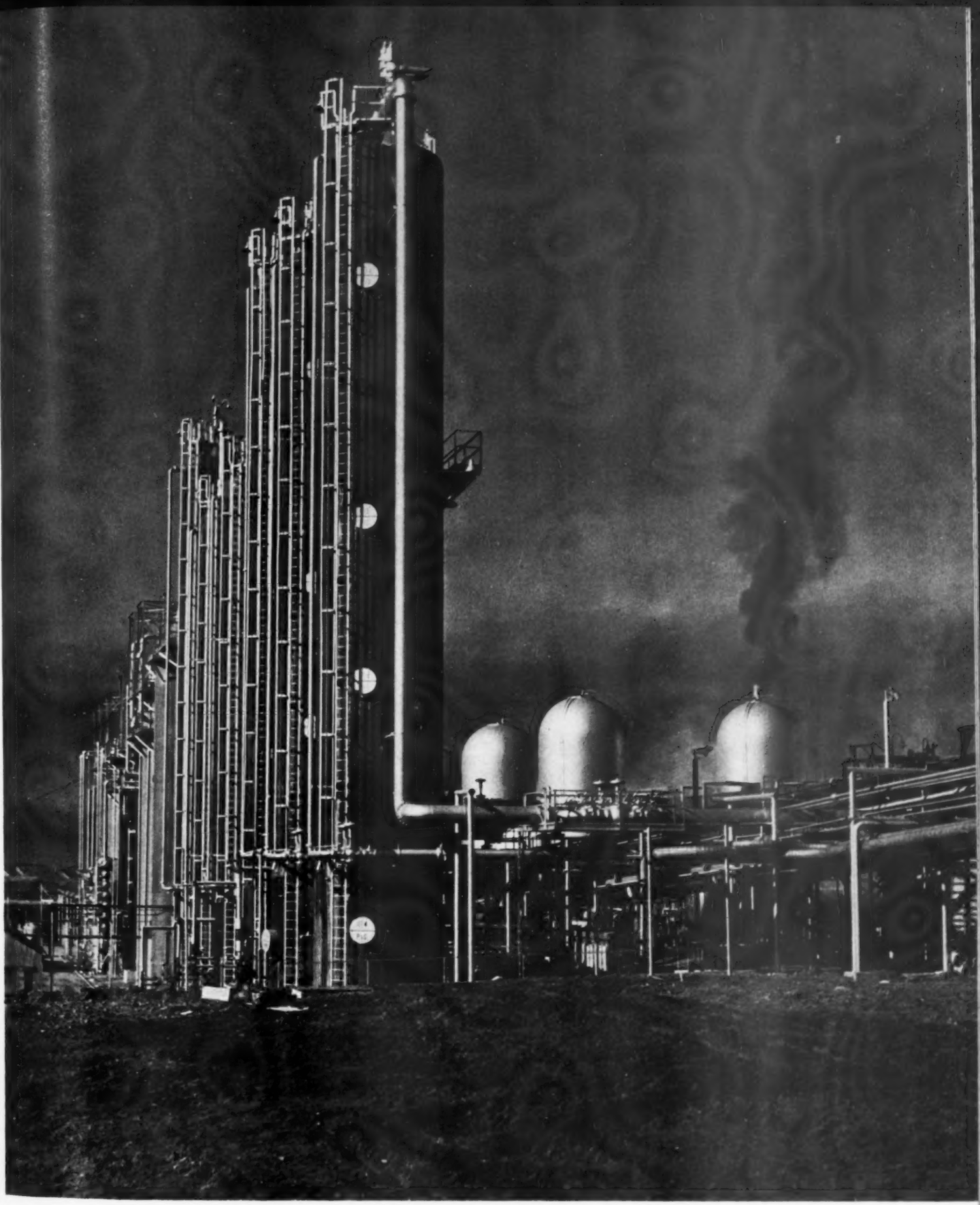
The lighter material removed in the second column, described in the preceding paragraphs, is C_5 (pentanes and pentenes) hydrocarbons, a large proportion of which is isopentane. It is worth noting that in addition to the neohexane produced, respectable proportions of isopentane are likewise being synthesized at this plant. This isopentane is formed in the alkylation coil by the junction of ethylene with propane.

An interesting factor in connection with the commercial plant installed by Phillips Petroleum Company is that commercial isooctane, isopentane and motor fuel are all made in conjunction with the manufacture of neohexane. In other words, all the ingredients necessary for the manufacture of high octane number aviation gasoline are made at the same location and are available for immediate blending to any desired specification.

In addition to the volatility advantages which neohexane has, it possesses a greater lead susceptibility than any other commercial high octane number material. This means that with a given quantity of lead, neohexane has a correspondingly greater octane number increase than commercial isocotane itself. This is a very important fact from an economic standpoint and further emphasizes the position which it plays in the manufacture of aviation fuels having antiknock values in excess of 100 octane number.

Although neohexane permits the production of a gasoline with a higher octane number than possible heretofore, it is believed that the top in octane numbers has not been obtained as yet. The development of neohexane permits the manufacture of aviation gasoline which is superior to anything heretofore available and as a result places this country at a considerable advantage over other countries in the aeronautics field.

The development of neohexane is just another step in the production of aviation gasolines with higher antiknock rating. While this represents a big advance for the aviation industry, it is believed that additional achievements in this field will be forecoming in the near future.



These fractionating towers are used by Phillips Petroleum Company for a large variety of pure hydrocarbons.

HOUDRY RESEARCH Seeks Development of Superior Catalysts

By Dr. W. O. Willcox

Houdry Process. Announced in 1938. Has Taken Important Position in Commercial Operations — Research Workers Now Study New Catalysts. Seek to Extend Application.

THE HOUDRY catalytic refining process first came to general notice in November, 1938 through a paper presented to the American Petroleum Institute by A. E. Pew, Jr., Eugene Houdry and associates. In that paper it was brought out that the process was able to effect several operations, the chief of which were:

Catalytic Cracking
Catalytic Treating
Catalytic Polymerization of Butenes

An account of the Houdry process as it stood in the fall of 1939 was published in the International Refinery issue of WORLD PETROLEUM for that year. At that time there were 10 Houdry plants in active operation and a number of others under construction. It is the purpose of this article to report on the overall commercialization of the chief operations of the process during the past year and the developments that have been made. The roster of Houdry plants now operating or in course of erection are given in Table 1.

During the past year there has been added to the Houdry catalytic cracking and treating unit of the Sun Oil Company at Marcus Hook and which was described in the above article, a catalytic reforming process, which makes this plant the first to have a combination unit for the complete catalytic processing of a crude oil. Sun Oil Co. will place in operation in November at Marcus Hook a large twelve case catalytic cracking unit which has been built for the catalytic conversion of gas oil stocks which were formerly thermally cracked. The same refinery also has installed a small semi-experimental unit for the catalytic polymerization of butenes in the liquid phase, and based upon the data obtained therefrom have built and are about to place in operation a commercial polymerization unit at their Toledo refinery.

In view of the National Defense Program and the necessity of providing fuel for a large number of planes it is interesting to note that the Paulsboro refinery of Socony-Vacuum Oil Company has been producing aviation fuel by the Houdry catalytic cracking process for over three years. With their recently completed unit they are charging Mirando and Cameron Meadows crude from the Gulf Coast. The crude charge is first topped to remove all constituents boiling under 400 deg. F. The bottoms from this topping operation are heated further and flashed in a tar separator, the tar being removed as a liquid, the vaporized portion passing to the catalytic cases for conversion. The catalytic gasoline produced is taken from the unit in two fractions, which if recombined, will give a 400 E. P. motor gasoline with a gross yield of 42 to 46 percent of the case charge.

For the production of aviation fuel the lighter catalytic gasoline fraction is stored and then treated in the same unit and by the same catalyst which produced it. During the treating operation the crude charge is cut off from the unit and suction taken on the raw aviation fuel tank. The operating conditions are adjusted for the treating operation so that the product will meet the desired specifications. This treating operation is required for the reduction of acid heat and to bring it from approximately 80 to below 20. It may be mentioned here that the more active type of synthetic catalysts for cracking gas oils and naphthas for aviation fuel are said to produce a gasoline having an acid heat of the order of 20. Generally this type of product requires no treatment. The aviation fuel has an A.S.T.M. octane number of 80 and with the addition of from 30 to 35 percent hydro co-dimer or other high octane blending agent and 3 cc. TEL per gal., the octane is raised to 100 by U. S. army method. Typical results when blending for 100 octane fuel are given as below:

	Base Stock	Alkylate	Blended Aviation Fuel
Gravity	65.2	70.7	67.6
R. V. P., Lb.	9.6	4.8	6.4
Acid Heat, deg. F.	21	2	10
O_2 Bomb Hrs., Min.	18.30	....	
Cu Dish Gum	2	1	<1
Glash Dish Gum	Nil	Nil	
Army Gum	<1	1	3
Octane-CFRM			
cc. TEL 0	80.7	93.2	84.8
1	88.6	....	92.8
2	91.4	....	95.2
3	93.3	....	98.6
Octane Army			
cc. TEL 3	....	....	99.9
Distillation ASTM			
IBP	106	120	102
10	126	182	137
50	187	220	204
90	259	233	238
E. P.	289	260	282
Recovery	98.5	98.5	98
Loss	1.0	0.5	1.4

Undoubtedly the Houdry process is able to produce a synthetic type of paraffinic aviation fuel which has a high octane value and which will meet requirements for air-cooled aviation engines. The importance of this resides in the fact that the higher octane

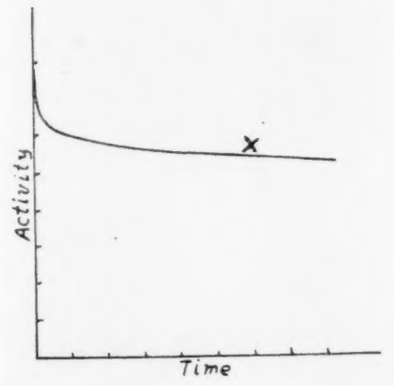
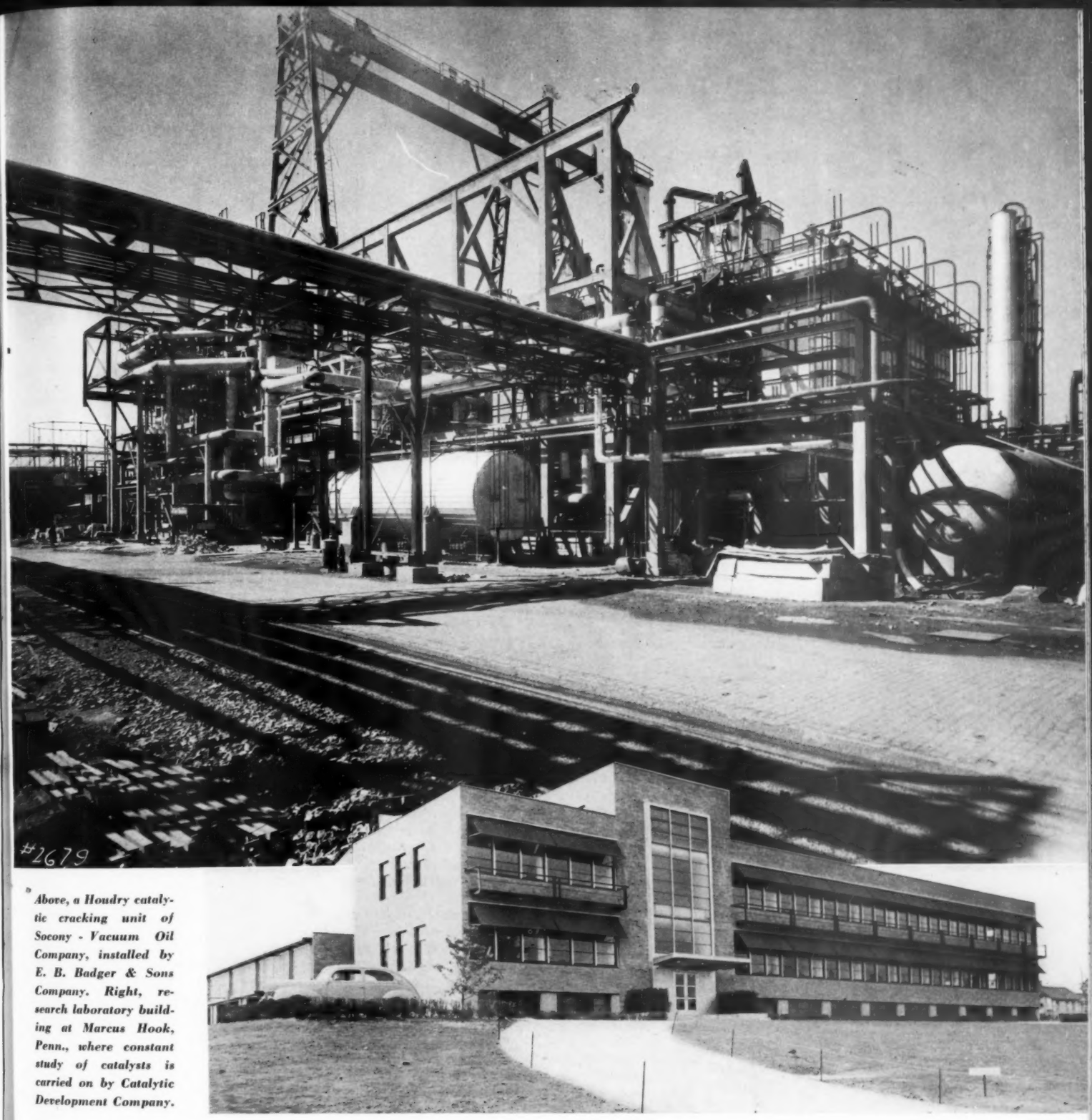


Figure 1

TABLE I

Company	Location	Type	Charging Stock	Capacity Charge Stock	Bbls./Day Case Charge
IN OPERATION—					
Socony-Vacuum Oil Co.	Paulsboro, N. J.	Cracking	Gas Oil	2,000	2,000
Sun Oil Co.	Marcus Hook, Pa.	Cracking	Reduced Crude	15,000	12,000
Raff. di Napoli	Naples, Italy	Cracking-V.Treating	Gas Oil	2,600	2,600
Magnolia Petroleum Co. No.1	Beaumont, Texas	Cracking	Crude	16,700	15,000
Sun Oil Co.	Marcus Hook, Pa.	Cracking-V.Treating	Crude	28,000	19,000
Socony-Vacuum Oil Co.	Detroit, Mich.	Cracking	Crude	19,400	10,500
Socony-Vacuum Oil Co.	Brooklyn, N. Y.	Cracking	Mixed	12,000	10,000
Sun Oil Co.	Toledo, Ohio	Cracking-V.Treating	Crude	28,000	19,000
Magnolia Petroleum Co. No.2	Beaumont, Texas	Cracking	Mixed	17,800	15,000
Socony-Vacuum Oil Co.	Buffalo, N. Y.	Cracking	Crude-Gas Oil	16,000	10,000
Sun Oil Company	Marcus Hook, Pa.	Reforming	Naphtha	8,000	8,000
Socony-Vacuum Oil Co.	E. St. Louis, Ill.	Cracking	Crude	18,400	10,000
Socony-Vacuum Oil Co.	Augusta, Kans.	Cracking	Crude	23,000	10,000
Socony-Vacuum Oil Co.	Paulsboro, N. J.	Cracking	Crude-Gas Oil	12,700	10,000
UNDER CONSTRUCTION—					
Raff. de Berre	Berre l'Etang, France	Cracking	Gas Oil or Reduced Crude	4,535 6,375	4,535 5,500
Tide Water Associated	Bayonne, N. J.	Cracking	Crude	Variable	16,600
Sun Oil Co.	Marcus Hook, Pa.	Cracking	Gas Oil	20,000	20,000
					195,200



Above, a Houdry catalytic cracking unit of Socony - Vacuum Oil Company, installed by E. B. Badger & Sons Company. Right, research laboratory building at Marcus Hook, Penn., where constant study of catalysts is carried on by Catalytic Development Company.

number of the catalytic gasoline will reduce the requirement for alkylate and hydro co-dimer blending medium. This obviously means economy in manufacture and is no mean addition to resources for a national supply of 100 octane fuel.

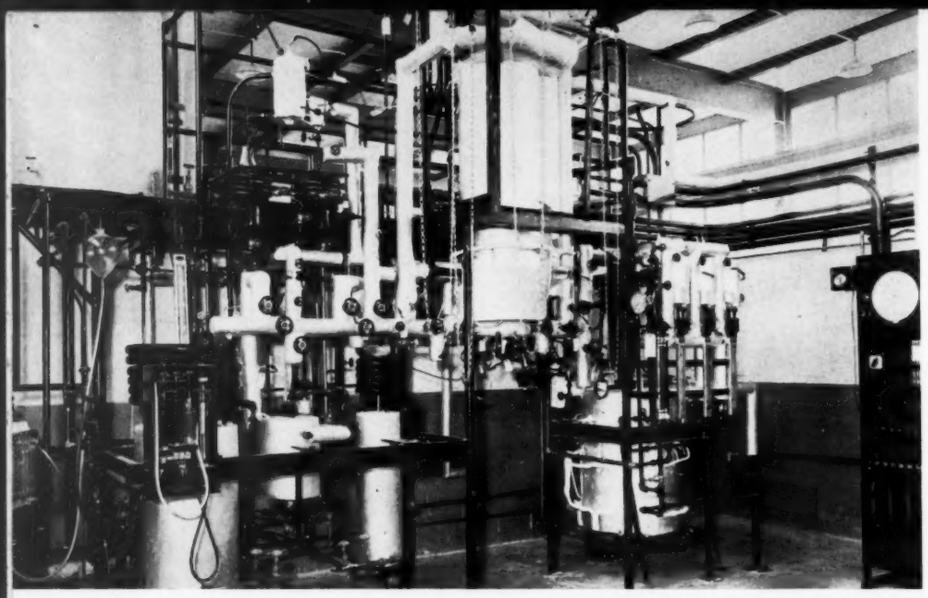
While it has been previously mentioned in many articles on the Houdry process that the high octane rating of the product extends into the heavier gasoline fractions, the following data is reported on the heavy naphtha resulting from splitting a 357 deg. F. E. P. catalytically treated distillate into a base aviation fuel and a bottoms:

Gravity	38.0 deg.
Acid Heat	10.0 deg. F.
Octane (CFRM)	79.3
Distillation ASTM	
IBP	272
10 percent	289
50 percent	309
90 percent	347
E. P.	396

Thus the naphtha bottoms from Houdry catalytic gasoline, after removal of the aviation cut, can be used for the production of high octane blended motor fuel.

200-DAY RUN

According to information obtained from the Houdry Process Corporation and from various refineries it appears that the process is maintaining its attribute of flexibility



A catalytic cracking pilot plant constructed for Catalytic Development Company laboratories at Marcus Hook to assist in the study of catalysts.

which allows of ready adjustment to the relative market demands for gasoline and fuel oil. In some localities, especially those in the east where the market for light fuel oil is good, the plants are allowed to make a gasoline yield of around 40 percent on case charge; in other places where fuel oil is not so important the gasoline yield is pushed up to around 50 percent or more as conditions may require. In shifting from one yield-base to another little more is required than a change in the rate of throughput.

The Houdry unit at Socony-Vacuum's Buffalo refinery was fired for run No. 1 on October 12, 1939. During October the charge to the unit was excess pressure-still stocks; these stocks were processed and depleted October 31, 1939, and on November 1, 1939, crude was charged to the unit along with the current work's production of Houdry pressure-still charging stocks—36/40 fuel oil from Olean and Olean gasolines; on December 3, 1939 the unit was shut down for inspection and to make some changes. During the shut-down the cases were topped off with catalyst and the ordinary check-up of pumps and equipment was made to assure that the unit could be kept on stream unless something unforeseen should happen during the cold weather.

Run No. 2 was started with the unit on stream at 4 P.M., December 7, 1939 and remained on stream until June 23, 1940; the cases were by-passed at 9 A.M. and the fires put out at 11 A.M., thus completing a continuous run of 200 days lacking five hours. The reason for taking the unit off was on account of dirty crude furnace tubes and the fouling of condenser tubes with dirty water. After cleaning, and the customary inspection, the unit was fired for Run No. 3 and was on stream on June 28, 1940, without any operating or mechanical difficulties.

TABLE 2

Monthly Percentage Yields of Houdry Unit at Socony-Vacuum's Refinery at Buffalo

	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Gasoline	48.44	51.19	48.91	48.66	48.36	46.99	49.65
Fuel Oil Dist.	25.28	25.34	25.16	23.52	24.21	24.35	20.37
Syn.Cr.Btms.	21.28	18.47	20.88	22.82	22.52	22.61	23.00
Gas and Loss	5.00	5.00	5.05	5.00	4.91	6.05	6.98

A detailed report from the Buffalo refinery gives a summary of percentage yields during the seven months' continuous operation of Run No. 2 (see Table 2). Similar results have since been maintained and during the first complete calendar year the operating time efficiency has been 97.4 percent.

From this table it appears that the yield in May is off about one percent, which is explained as follows:

During that month there was an unusual special demand for a special gasoline, which ordinarily is not more than four percent, but which in that month rose to 11 percent.

The inspection of the unit after Run No. 2 did not show the unit to be particularly bad, the crude furnace tubes were dirty but not coked, there was no dirt or coke in the tar separator, synthetic crude tower and topping tower; no coke in Leach vapor exchangers or vapor lines, but the main trouble was dirty water condenser tubes.

An interesting statement on the quality of the gasoline produced at this plant is to the effect that "a sample of Houdry stabilized gasoline placed in the sunlight or direct light for six months darkened from 15 color to 12 color, with no deposit of sediment".

CATALYST

In refinery circles there has been much interest in the matter of how long a Houdry catalyst would stand up under continuous operation. The past policy of the Houdry Corporation has been to base economic studies for new installations on a catalyst life of at least six months. This policy was conservative but arose from experience in the developmental period, which showed a gradual deterioration in catalyst activity, somewhat as schematically indicated in Figure 1 where activity is plotted against time in operation. During operation the activity curve becomes nearly flat whether the unit is operated to produce 40 percent or 50 percent, or some other percentage yield of gasoline on case charge, as the operator may desire. It has been expected that the activity would gradually decrease to some point (indicated by X in the diagram) where it would become uneconomic and should be replaced. As stated, for estimate purposes X has been arbitrarily fixed at six months.

To date there have been three changes of catalyst, namely, at Magnolia Petroleum Company's No. 1 Houdry unit at Beaumont, Texas, after nine months; Sun Oil Company's 12-3 Houdry unit at Marcus Hook, Pa., after 14 months and Socony-Vacuum Oil Company's Houdry unit at Brooklyn after 12 months.

However, some doubt has been cast on the theory that a Houdry catalyst will necessarily deteriorate in use. Some refinery superintendents whose Houdry units have been in operation a long time inform the writer that after the brief initial shaking down period there has been no noticeable decline in catalyst activity. Experience at the Socony-Vacuum unit at Buffalo, which has been referred to above, is a case in point; here the monthly percentage yields during a seven-months' run have been almost monotonously regular except for small plus or minus variations due to external circumstances, or to trade conditions that had to be met.

Apparently, avoidance of progressive deterioration is largely a matter of adherence to proper operating conditions, which are now better understood than was the case in the early history of the process.

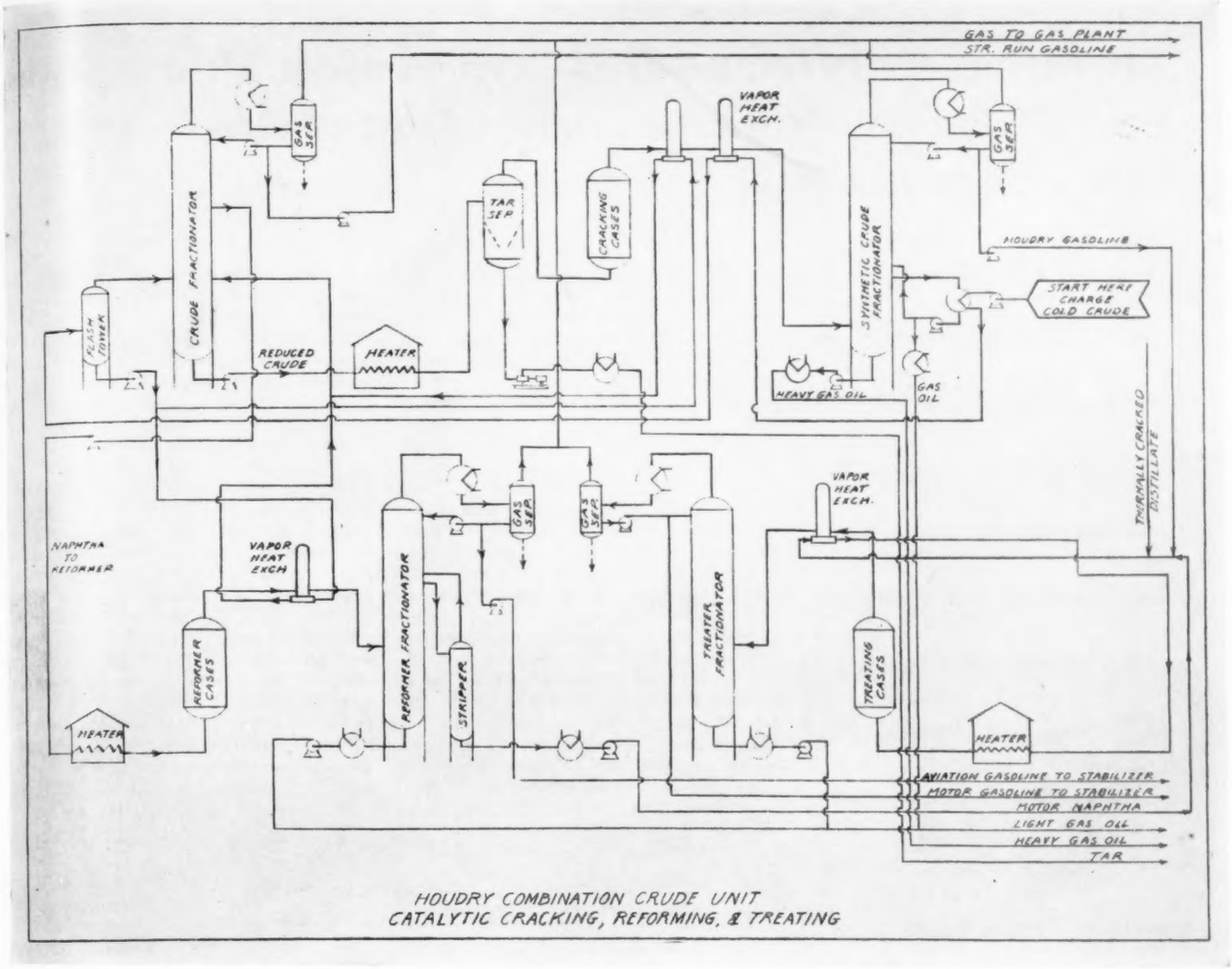
NEW CATALYST

The writer has been informed that the Houdry Process Corporation has developed a new catalyst which is now in production and will later on be available in quantity for particular purposes. Whereas the catalyst base previously in use was processed from natural clays or zeolitic materials, the new one is a purely synthetic product. The new catalyst has passed through the pilot plant stage, and while no commercial data are available it is said to have given evidence of the following qualities: It gives a better yield of gasoline from the same charging stock than the old one; the increased yield is said to be of the order of 10 to 20 percent. The motor gasoline produced is of a better quality in respect to lead susceptibility; it is also better in respect to color, gum, and acid heat. A very interesting fact is that the gas issuing from the catalyst case contains a more than ordinary proportion of isobutane, the ratio of the normal to the iso compound being of the order of 15:85.

At present the new catalyst appears to be primarily adapted for treating gas oils and naphthas but its use will be extended to heavier charge stocks.

RESEARCH

At Marcus Hook the Houdry Process Corporation has just completed what is perhaps the largest and most completely furnished laboratory in the world devoted exclusively to research on the catalytic treatment



HOUDRY COMBINATION CRUDE UNIT
CATALYTIC CRACKING, REFORMING, & TREATING

of oils. This imposing institution was built at an approximate cost of $700,000. Besides extensive facilities for chemical synthesis of new materials and for the chemical and physical testing of these materials and their reaction products, there is an elaborate array of equipment for conducting experiments on catalytic refining on both small and semi-plant scales. About 110 technologists and operators of various classifications are employed in research. This refers to research work only, and does not include operations of the old Houdry laboratory which has been taken over and operated by E. B. Badger & Sons Co. (licensing agents for the Houdry processes) for commercial evaluation work only.

In passing through the workrooms of this institution the visitor will perhaps be less impressed by the obviously complete equipment than by a feeling that the researchers must have accumulated a great wealth of ideas to require such facilities for their working out. Evidently the Houdry Corporation has tangible reason to believe that new and worthwhile developments are possible. The new catalyst above referred to is one fruit of this intensive research.

Figure 2.

The general layout of the Houdry combination cracking - reforming - treating unit (known as the 12-3 plant) at Sun Oil Company's Marcus Hook refinery is shown on the accompanying flow diagram.

COMBINATION

The charge of cold crude goes through the more or less conventional topping and fractionating process to produce gas for the gas plant, straight run gasoline, naphtha for the reforming unit and a reduced crude for the catalytic cracking cases.

In the new reforming member of this unit the straight run naphtha is first sent through a heater and then through the catalytic reformer cases. After exchanging heat with the bottoms from the crude charge flash tower the reformer vapors enter the reformer fractionator, which yields an overhead of gas and aviation gasoline base and a side stream from which motor naphtha is stripped; the bottoms from the reformer fractionator are a light gas oil.

In the meantime the reduced crude from the crude fractionator passes through the previously described heaters, tar separator and Houdry catalytic cracking cases. The cracked product, which now has the character of a synthetic crude, passes through a synthetic crude fractionator for separation of gas, Houdry motor gasoline, light and heavy gas oils.

The Houdry gasoline from the synthetic crude fractionator is now mixed with any available thermally cracked distillate from other departments of the refinery, and, after heat exchanging, is vaporized in a heater and passes through the previously described catalytic treater cases and goes into the treater fractionator for separating gas and motor gasoline.

No yield figures from this catalytic cracking-reforming-treating system of the 12-3 plant at Marcus Hook are as yet available for publication, as the unit has only recently been put in operation as a whole and has been deliberately operated in a way to determine certain factors regarding catalyst life, regeneration, etc. The same applies to Sun Oil's large Toledo polymerization unit at Toledo which is still only in its preliminary operating stage.

Naphtha Polyform-Gas Reversion Processes *Yield High Octane and Important War-Time Aromatics*

The Following Paper by J. E. Bogk, Phillips Petroleum Company, P. Ostergaard, Gulf Oil Corp. and E. R. Smoley, The Lummus Company, is Now Being Delivered at the Annual Meeting of the American Petroleum Institute—It Deals with Economic Use of Outside Gasses with Naphtha for Production of High Yields of High Octane Motor Fuel.

DURING the past ten years antiknock improvement of motor fuel has been an important factor in the trend toward better performance. Early improvement was along conventional lines, incorporating increased application of cracking, with attendant improvements in still design, and the use of thermal reforming. More recently the octane number levels reached, have made it necessary to turn more and more to new processes. Catalytic and thermal gas polymerization are now in extensive use for augmenting motor fuel yield and raising the overall octane number, and recently, catalytic cracking has been applied. Most of the new processes when used in conjunction with cracking operations, provide more than merely additive improvement; a polymerization unit, for example, permits production of a higher octane number gasoline with a reduced penalty in the form of gas loss. However, in fully combining thermal cracking or reforming with thermal gas polymerization to effect both conversions wholly or partially in the same reaction zone, it has been found possible to elevate materially octane levels and improve economics well above those obtainable by conducting the conversion steps separately. These processes, generally speaking, are carried out in more or less conventional thermal equipment and their effectiveness depends upon conducting the conversion steps under proper conditions. This paper is concerned with the joint conversion of naphtha and hydrocarbon gases to produce high yield of motor fuel with octane numbers in the range of 70 to 80 CFR-ASTM.

GAS-NAPHTHA

A brief review of the chemistry of gas polymerization will aid in explaining the joint conversion of gas and naphtha.

The thermal conversion into gasoline of propane, butane and the gaseous olefins, which represent the convertible part of still gases, is effected by heating them either singly or in mixture to a temperature in the range of 800 to 1150 deg. F. while maintaining a pressure of 500-3000 lbs. per sq. in. in the reaction zone.

Concentrated gaseous olefins—ethylene, propylene, butylene—polymerize directly into a high yield of motor fuel, the product being mainly higher olefins. The reaction is accelerated by pressure, and above 500 lbs. will take place at or even below the usual oil cracking temperatures.

The conversion of the gaseous paraffins, propane and butane, into gasoline is more complicated. The paraffin first breaks up into smaller paraffin and olefin molecules, then the olefin molecules so formed undergo conversion into gasoline through concurrent olefin-olefin polymerization and olefin-paraffin union or alkylation reactions. By cracking at low pressure it is possible to convert propane or butane almost completely into lighter gaseous olefins and paraffins, but when the pressure is high the polymerization of these olefins follows closely on the heels of the cracking reaction and gasoline begins to form when only a small part of the original paraffin has been decomposed. As the time of residence in the cracking zone is increased, progressively larger quantities of gasoline range hydrocarbons are formed, the gasoline becomes richer in cyclic hydrocarbons, tar formation then begins and accelerates, until carbon formation becomes evident. The onset of carbon formation, as in conventional crack-

TABLE I

Operating Data of Naphtha-Gas Reversion Units

	Run No. 1	Run No. 2	Run No. 3	Run No. 4	Run No. 5
Charge:					
Naphtha, percent	100.0	100.0	100.0	100.0	100.0
Outside Gas Feed, percent on Naphtha	100.0	100.0	100.0	100.0	100.0
Total Charge, percent on Naphtha	200.0	200.0	200.0	200.0	200.0
Gasoline Yield: (Based on Naph. Charge)					
Percent 8.5 PSI-RVP at 100 deg	135	131	134	128	119.5
API Gravity	61.3	59.5	62.0	61.5	59.8
Distillation, ASTM					
IBP	95	95	93	98	98
10 percent	125	143	123	132	137
50 percent	204	224	210	204	203
90 percent	353	347	345	339	321
E. P.	402	410	406	408	405
Sulfur (lamp)	.06	.02	.09	.10	.09
CFR-ASTM Oct. No. +1 cc TEL/Gal. @ 6.5 # R.V.P.	69.2	67.3	69.0	73.0	75.5
CFR-ASTM Oct. No. +2 cc TEL/Gal. @ 6.5 # R.V.P.	74.2	73.6	74.0	77.1	79.1
CFR-ASTM Oct. No. +3 cc TEL/Gal. @ 6.5 # R.V.P.	78.0	78.0	78.0	79.8	81.2
	80.5	80.6	80.5	81.0	82.6
Fuel Oil Yield—					
Percent on Naphtha	Average 3 percent				
API Gravity	12.0				
SFV @ 122 deg. F	90.0				
BSXW	0.2				
Naphtha Charge:					
Gravity, deg. API	60.6	61.1	60.6	59.6	58.7
Distillation, ASTM					
IBP	110	99	110	105	104
10 percent, deg. F	156	150	160	157	162
50 percent	244	242	250	255	261
90 percent	364	366	375	400	410
E. P.	424	423	428	446	450
Percent Evap. at 212 deg. F.	.....	34	.....	31	.....
Aniline Point	133.2	132.8	133.9	136.2	134.2
Percent Sulfur (lamp)	.....	.....	.....	.12	.11
CFR-ASTM Oct. No.	49.0	46.4	47.8	.....	49.4
Outside Gas Feed:					
Analysis, L. V. percent					
H_2	2.7	0.6	2.8	2.8	2.6
C_1	9.7	2.9	11.0	23.9	13.9
C_2	0.7	0.2	1.0	1.5	0.5
$C_2^=$	44.9	12.5	52.3	54.4	38.6
C_3	5.5	2.7	4.7	15.2	5.9
$C_3^=$	32.2	74.3	26.0	2.2	35.5
C_{4s}	3.9	6.6	2.0	.....	2.9
C_{4-s}	0.4	0.2	0.2	.....	0.1
C_{4s}	10.1	9.5	7.7	16.7	9.3
Total Unsaturates, L. V. percent	.....	.....	.....	0.83	0.44
Sulfur (lamp).					

TABLE II

Yields, Products and Operating Data of Naphtha Polyform Units With and Without Outside Gas

Operation Number:	1			2			3			4			5			6		
	Polyforming Naphtha —5% (23.5–28.5% on E. Venez. Crude)			Polyforming Naphtha —10% (18.6–28.5% on E. Venez. Crude)			Polyforming Naphtha 15% (13.4–28.5% on E. Venez. Crude)			Polyforming Naphtha —10% (18.6–28.5% on E. Venez. Crude)			Polyforming Naphtha With Outside Gas Feed (M. C. Naphtha 20–32% on Crude)			Polyforming Naphtha With Outside Gas Feed (M. C. Naphtha 26–34% on Crude)		
1. Operating Data:	Bbl./D	Vol. %	Wt. %	Bbl./D	Vol. %	Wt. %	Bbl./D	Vol. %	Wt. %	Bbl./D	Vol. %	Wt. %	Bbl./D	Vol. %	Wt. %	Bbl./D	Vol. %	Wt. %
Charge:																		
Naphtha	4,000	100	100	4,000	100	100	4,000	100	100	4,000	100	100	2,515	100	100	1,111	100	100
Outside Gas (F. O. E.)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2,286	90.9	96.9	1,894	170.5	188.9
Total	4,000	100	100	4,000	100	100	4,000	100	100	4,000	100	100	4,801	190.9	196.9	3,005	270.5	288.9
Yields:																		
Gasoline	3,040	76.0	74.3	3,350	83.9	82.0	3,470	86.8	85.5	2,580	64.6	64.4	2,480	98.6	94.98	1,337	120.3	113.7
Gas (F. O. E.)	467	11.7	11.7	360	9.0	9.4	336	8.4	9.0	709	17.7	19.5	2,118	84.22	88.43	1,565	140.9	136.9
Tar	446	11.3	14.0	296	7.4	8.6	180	4.5	5.5	540	13.5	16.1	198	7.89	10.27	83	7.5	9.9
Total	3,953	99.0	100.0	4,006	100.3	100.0	3,986	99.7	100.0	3,829	95.8	100.0	4,796	190.71	193.68	2,985	268.7	280.5
Temperature, deg. F.																		
Charge to Furnace		475			475			475			425			425			360	
Product from Furnace		1,090			1,080			1,085			1,125			1,075			1,040	
Pressures, Lbs./Sq. In.:																		
Charge to Furnace		1,250			1,250			1,250			1,250			1,250			1,550	
Products from Furnace		1,000			1,000			1,000			1,000			1,000			950	
Fractionating System		300–350			370–400			300–350			300–350			350			370–290	
Quantities:																		
Rich Naphtha Circulation, B/D		9,220			9,000			9,030			12,100			12,100			6,660	
Gaseous Charge M-CFD														7,480			6,310	
Residue Gas M-CFD		2,620			2,025			1,910			4,220			8,420			6,440	

Laboratory Inspection:	Charge	Dist.	Tar	Charge	Dist.	Tar	Charge	Dist.	Tar	Charge	Dist.	Tar	Charge	Dist.	Tar	Charge	Dist.	Tar
Gravity, deg. API	45.7	50.0	16.1	47.9	52.0	22.9	50.8	53.9	17.4	47.9	48.5	18.8	51.8	58.8	9.5	51.3	61.9	8.7
Distillation, ASTM																		
O. P. at: deg. F.	318	92	355	266	100	375	230	96	348	266	98	352	160	91		158	91	
E. P. at: deg. F.	465	412		431	404		412	400		431	406		446	409		426	378	
10 percent at: deg. F.	329	146	386	290	152	419	258	140	393	290	152	408	236	126		255	106	
50	349	298	500	311	282	510	286	259	511	311	270	518	324	228		325	196	
90	409	372		372	349		358	335		372	336		407	366		380	330	
Reid Vapor Pressure, Lbs./Sq. In.		9.1			8.2			10.0			7.5					1.7	10.2	
Color		+1			+1			+14			+2		+18	+30		+26	+30	
Gum-ASTM, mg./100cc		5			7.4			6.0						1			5	
Copper Dish, mg./100 cc		85			55			12						10			79	
Oxygen Stability (E. G. C.) min. at 210 deg. F.		190				180		165			155			43			30	
Acid Heat, deg. F	3	96		2	89		2	92			101		2	95		3	115	
Aniline Point, deg. F	126	65		136	71		116	71			39		136	96		130	85	
Viscosity, SUV at 100 deg. F., sec.	.....	.....	49	.....	.....	41	.....	.....	48	.....	.....	47	.....	.....	1,044	.....	.....	447
210 deg. F., sec.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
130 deg. F., sec.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Carbon Residue, Conradson, percent	.....	.....	7.4	.....	.....	3.3	.....	.....	6.5	.....	.....	8.1	.....	.....	5.9	.....	.....	12.78
	.....	.....	0.2	.....	.....	0.2	.....	.....	0.2	.....	.....	0.6	.....	.....	0.2	.....	.....	0.25
B. S. & W., percent	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pour, deg. F.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Flash Point (P. M.), deg. F.	.....	.....	140	.....	.....	164	.....	.....	152	.....	.....	160	.....	.....	.....	.....	.....	.....
Octane Number, ASTM: clear	40.9	76.6		47.3	76.1		49.7	76.1		47.3	80.1		39	75.2		36.9	76.7	
+1 cc. TEL	50.0	81.3		56.9	82.0		59.6	82.7		56.9	83.7			80.8			80.7	
+3 cc. TEL	60.6	83.8		66.1	84.4		70.5	85.1		66.1	85.6			83.4			83.5	
Research: clear	46.0	88.7		50.1	86.4		51.5	85.5		50.1	92.7			88.0			88.2	
+1 cc. TEL	49.8	93.7		58.3	91.2		60.1	92.2		58.3	96.4			92.1			92.0	
+3 cc. TEL	62.5	95.6		70.0	94.8		71.3	94.8		70.0	98.0			94.7			95.0	

Gas Analysis:	Feed	Residue		Feed	Residue		Feed	Residue		Feed	Residue		Feed	Residue		Feed	Residue	
Specific Gravity (Air = 1)	.....	0.708	.....	.....	0.732	.....	.....	0.690	.....	.....	0.671	.....	1.11	0.918	.....	1.18	0.959	
Composition, percent by volume:																		
Hydrogen and Methane	.....	63.6	.....	.....	60.9	.....	.....	65.4	.....	.....	68.4	.....	36.5	46.7	.....	30.2	41.5	
Ethene	.....	8.1	.....	.....	8.9	.....	.....	8.3	.....	.....	6.8	.....	2.8	5.4	.....	3.0	3.7	
Ethane	.....	26.4	.....	.....	27.8	.....	.....	24.3	.....	.....	23.0	.....	13.6	23.8	.....	18.6	25.8	
Propene	.....	.....	.....	.....	1.0	.....	.....	0.4	.....	.....	.....	.....	8.7	5.8	.....	10.2	7.2	
Propane	.....	1.9	.....	.....	3.4	.....	.....	1.6	.....	.....	1.8	.....	24.0	15.4	.....	19.4	16.2	
Butenes	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.8	.....	.....	6.7	1.9	
Butanes	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7.5	2.9	.....	8.3	3.6	
Pentanes	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.7	.....	.....	3.6		
Hexanes	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.4					
Unsaturates	.....	8.1	.....	.....	9.9	.....	.....	8.7	.....	.....	6.8	.....	.....	.....	.....	.....	.....	.....
Total	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	100	100	.....	100	100	

ing, sets a definite limit on the fraction of the original paraffin that can be decomposed per pass at high pressure in the conversion zone, making it necessary to recycle unreacted hydrocarbons in order to obtain highest gasoline yields. The lightest products, methane and ethane, crack with great difficulty and, considered from the yield standpoint, should not be present in excessive amounts in the furnace charge. Olefins, as well as paraffins in the C_3-C_4 range, are suitable for recycling.

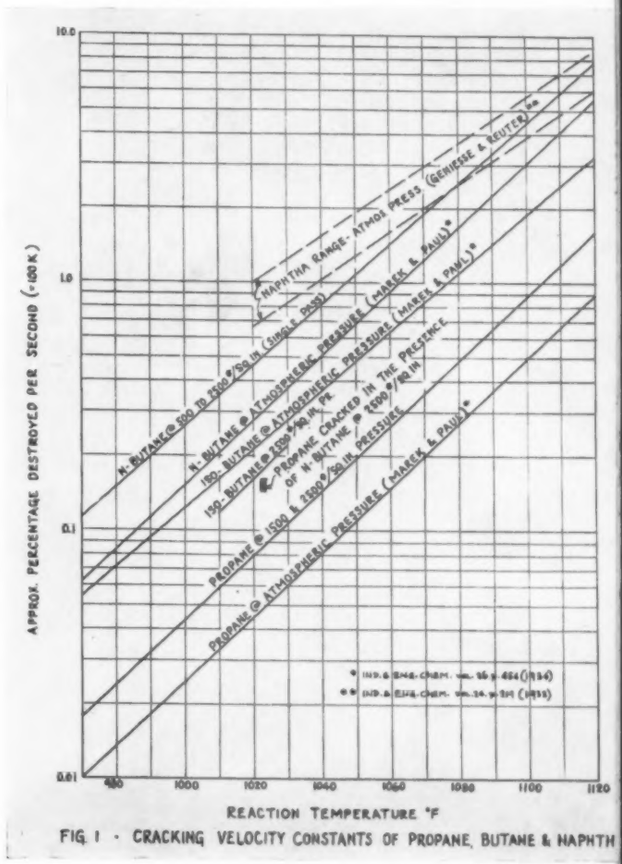
The yield of gasoline depends on the composition of the charging stock, the temperature, pressure and reaction time. Within limits, temperature and reaction time are interchangeable, short times and high temperatures giving approximately the same yield of gasoline as long times and low temperatures in recycle operation. Drastic time-temperatures make for a product rich in aromatics and with a high octane number.

The individual paraffins differ widely in their resistance to the initial decomposition, becoming more refractory as their molecular weight decreases. Thus, propane requires about four times the reaction time at a given temperature to effect a stated amount of decomposition as does n-butane. Mixtures of propane or butane with olefins form gasoline at conditions intermediate to those for either olefins or paraffins alone and are responsive to high pressures, which favor alkylation reactions and high yields.

The decomposition rates of propane and butane, as well as some naphthas, are shown plotted against temperature in Fig. 1. These constants were calculated by substituting the proper values in the equation for a first-order reaction:

$$k = \frac{2.303}{t_{(sec)}} \log \frac{100}{100 - x}$$

where t is reaction time in seconds and x is the percent of the hydrocarbon destroyed. The values of t and x have been determined experimentally by maintaining the hydrocarbons under known conditions of temperature and time and determining the extent of decomposition from analyses of the products obtained. The decomposition rate doubles for an increase in temperature of 25-30 deg. F. The effect of pressure on the decomposition rate of saturated material is small. High pressure serves mainly to accelerate the gasoline-forming olefin polymerization and alkylation reactions, and highest per-pass as well as ultimate gasoline yields are obtained at the


APPROX. PERCENTAGE DESTROYED PER SECOND (=100 K)
10.0
1.0
0.1
0.01
NAPHTHA RANGE - ATMOS PRESS (GENIESSE & REUTER)**
N-BUTANE @ 500 TO 2500 #/SQ IN (SINGLE PASS)
N-BUTANE @ ATMOSPHERIC PRESSURE (MAREK & PAUL)*
ISO-BUTANE @ 2350 #/SQ IN PR.
ISO-BUTANE @ ATMOSPHERIC PRESSURE (MAREK & PAUL)*
PROPANE CRACKED IN THE PRESENCE OF N-BUTANE @ 2500 #/SQ IN
PROPANE @ 1500 & 2500 #/SQ IN PRESSURE
PROPANE @ ATMOSPHERIC PRESSURE (MAREK & PAUL)*
* IND. & ENG. CHEM. vol. 26 p. 484 (1934)
** IND. & ENG. CHEM. vol. 24 p. 391 (1932)
980
1000
1020
1040
1060
1080
1100
1120
REACTION TEMPERATURE °F
FIG. 1 - CRACKING VELOCITY CONSTANTS OF PROPANE, BUTANE & NAPHTH

highest pressures. At a pressure of 2,500 lbs. per sq. in. a per-pass gasoline yield amounting to approximately 15 and eight percent by liquid volume from butane and propane, respectively, can be obtained before carbon formation becomes marked. At somewhat lower pressures, 1,000-1,500 lbs., the maximum obtainable gasoline yield per pass decreases slightly.

In Figure 2 is shown the ultimate yield of gasoline from propane and butane cracked at 2,500 and 1,500 lbs. pressure plotted against the recycle ratio resulting when all of the C_3 and C_4 hydrocarbons surviving passage through the reaction zone are recycled. These values were calculated from single-pass experimental data and the range covered is fairly broad. Carbon formation would probably be encountered if propane were cracked with low recycle ratios in the order of one or two. The trends shown indicate a marked yield improvement as conversion per pass is decreased, i.e., recycle ratio increased.

The charging stock composition affects not only the yield but the character of the gasoline formed. The gasoline-forming reactions must proceed under the same time-temperature conditions as are needed to effect the initial decomposition of the original charging stock. Consequently, gasoline formed by cracking propane under high conversion conditions has been subjected to much more drastic conditions of time-temperature than a similar product from n-butane. As a result of this, the gasoline from propane cracking will usually contain larger percentages of the heat-stable cyclic and aromatic compounds.

The reactions leading to the formation of gasoline and heavier products are complex and not well understood. As stated previously, olefins when in concentrated form readily polymerize to yield higher-boiling products which are largely olefinic. This reaction is sensitive to pressure, and as the concentration of the olefins is reduced by paraffin diluents, higher pressures are required to maintain reaction velocity. If reaction temperature is increased the tendency to form cyclics which may dehydrogenate to aromatics becomes marked. The olefin polymerization reaction velocity is doubled for a temperature increase of approximately 45 deg. F. This compares with 30 deg. F. to double the initial decomposition reactions. Consequently, as temperature is increased cracking tends to outstrip the polymerization and the olefin content of the effluent gases from the reaction coil increases.

In addition to olefin-olefin polymerization, alkylation reactions wherein gaseous olefins, particularly ethylene, react directly with paraffins to yield higher-boiling paraffins also proceed. These reactions are also accelerated by increased pressure and temperature, the rate doubling for a temperature increase of approximately 40 deg. F. Under favorable conditions of high pressure, moderate temperature and high cycle ratio, a substantial part of the gasoline may be formed through these alkylation reactions.

Products boiling above the gasoline range probably are formed from the gasoline through a series of reactions involving olefin polymerization, cyclization, aromatization, and condensation. Coke formation closely follows tar formation and probably results from the coking of high-boiling tars which have reached their dew-point and are precipitated on the tube walls.

An inspection of Figure 1 brings out that naphtha is much less refractory than saturated propane or butane. A mixture of naphtha and propane, for example, must be converted at a time-temperature no more than sufficient to effect extensive once-through reconstructing of the naphtha, short of coking. This automatically dictates a limited destruction of the accompanying propane, which for its complete conversion, must be recycled in a volume 7 to 10 times the net volume supplied. Butane, being less refractory, requires a 3 to 5 ratio. These ratios are somewhat lower than would be calculated for the individual velocity constants given in Figure 1, since in mixtures some cooperation is obtained, in that cracking velocity of the propane and butane is increased, and these hydrocarbons are also consumed by alkylation and other synthesis reactions. Figure 2 brings out that high recycle ratios make for high ultimate gasoline yield from gaseous paraffins.

The admixed gases in addition have a pronounced physical effect on the naphtha reforming which takes place concurrently with gas polymerization. In reforming naphtha alone, the octane number of the motor fuel increases as the severity of the thermal treatment increases up to the point where coke formation sets in, placing a limit on the degree of conversion. Coke formation is usually ascribed to the development of tar in increased amount and of increasingly high dew-point which at length deposits as a liquid phase and goes to coke *in situ*. The reduction of partial pressure deters tar condensation, and at pressures of 1,000 lbs. more or less, the gases tend further to deter tar deposition by reducing the critical temperature and lowering the dew-point.

For the reasons given, conversion conditions at 1,000 lbs. pressure, for example, can be made quite drastic with attendant octane number improvement, when gas conversion

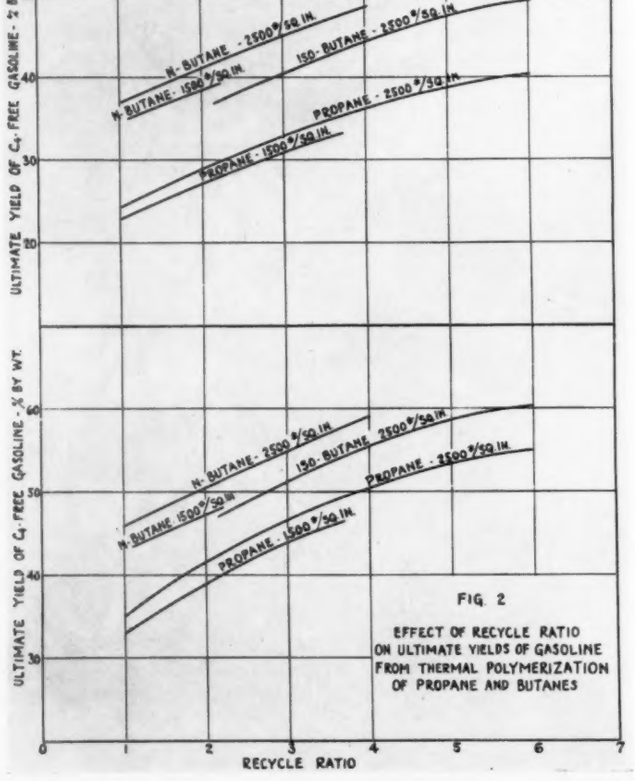

ULTIMATE YIELD OF C4-FREE GASOLINE - % BY VOLUME
ULTIMATE YIELD OF C4-FREE GASOLINE - % BY WT.
N-BUTANE - 2500 #/SQ IN.
ISO-BUTANE - 2500 #/SQ IN.
N-BUTANE - 1500 #/SQ IN.
PROPANE - 2500 #/SQ IN.
PROPANE - 1500 #/SQ IN.
RECYCLE RATIO

FIG. 2

EFFECT OF RECYCLE RATIO ON ULTIMATE YIELDS OF GASOLINE FROM THERMAL POLYMERIZATION OF PROPANE AND BUTANES

TABLE III

Yield Analysis From Polyforming Mid-Continent Naphtha With Outside Gas Charge

Operation	5		6	
	Bbl./D	Volume Percent of Naphtha	Bbl./D	Volume Percent of Naphtha
Charge:				
Naphtha	2,515	100.0	1,110	100.0
Outside Gas F. O. E.	2,286	9.0	1,894	170.5
Total	4,801	190.9	3,005	270.5
Yields:				
Gasoline	2,480	98.6	1,337	120.3
Gas	2,118	84.2	1,565	140.9
Tar	198	7.89	83	7.5
Total	4,796	190.71	2,985	268.7
C_3 in outside feed gas	1,575		1,197	
C_3 in residue gas	1,150		972	
C_3 in net gas charge	425		225	
C_4 in outside feed gas	680		698	
C_4 in residue gas	185		220	
C_4 in net gas charge	495		478	
Total C_3 and C_4 charge	920		703	
C_5 in outside gas	110		146	
Gasoline from:				
C_3 and C_4 gas feed	401	16.0	312	28.1
C_5+ in outside gas	110	4.4	146	13.2
Naphtha	1,969	78.2	879	79.0
Total	2,480	98.6	1,337	120.3
Ratio—C_3 and C_4—Naphtha Feed		.365		.635
Percent in net gas feed		46.5		32.0
Percent C_4 in net gas feed		53.5		68.0
Yields of distillate from C_3 and C_4 net gas charge		43.5		44.3
O. N. CFR-ASTM of total distillate		75.2		76.7

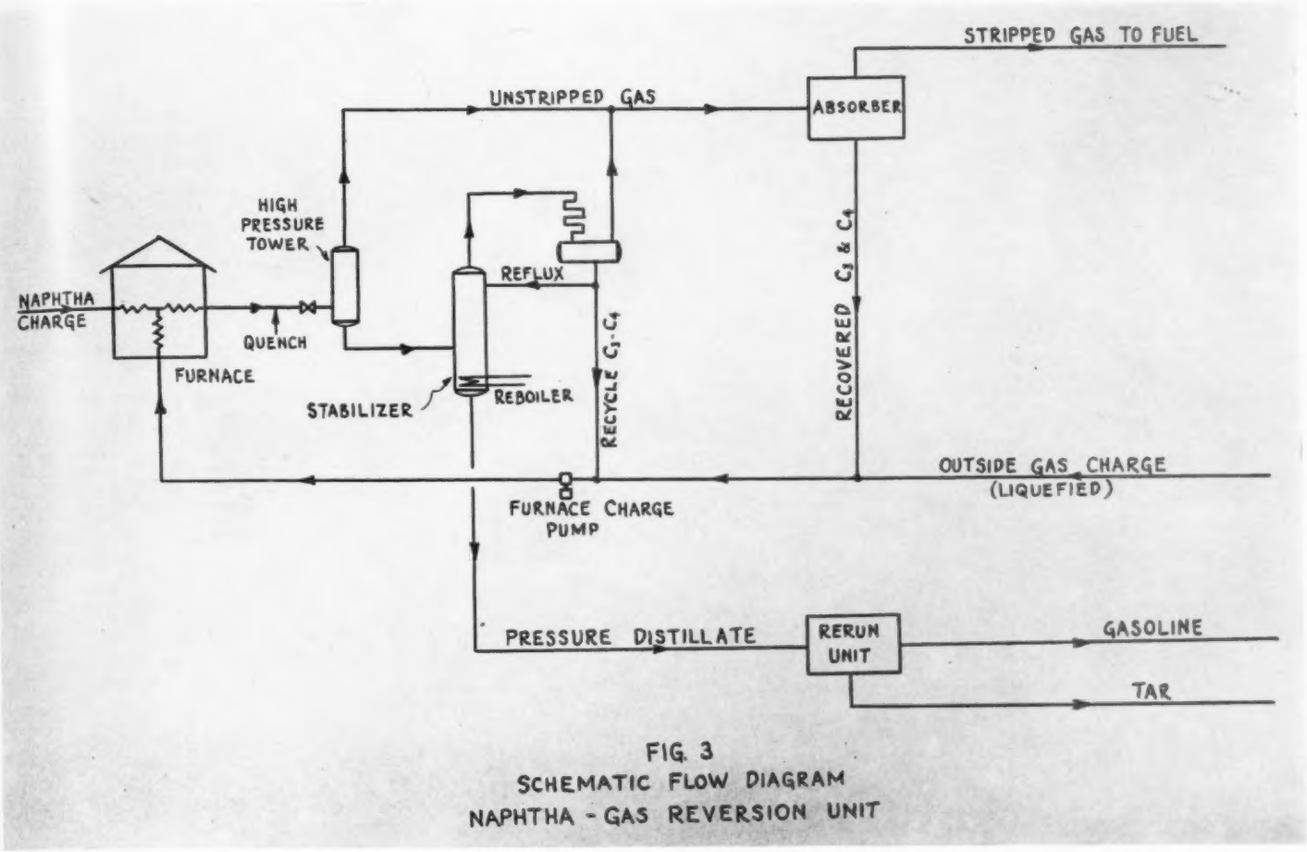


FIG. 3
SCHEMATIC FLOW DIAGRAM
NAPHTHA - GAS REVERSION UNIT

stock is admixed with naphtha in sufficient relative amount, usually in excess of volume for volume, to produce the physical effects described. The chemistry of the joint conversion reaction is imperfectly understood. It is certain that a large fraction of the naphtha, with drastic but non-coking conditions, is converted into gaseous olefins and some paraffins. These, together with the gaseous hydrocarbons introduced, undergo gas polymerization with olefin polymerization predominating and alkylation taking place to a minor degree. As more naphtha breaks up, more polymer gasoline forms, supplementing the gasoline resulting from reconstructing reactions of the naphtha itself.

Mild operating conditions are indicated when higher yield at a lower octane number level is the result desired. Gas loss from the naphtha can in this way be reduced. However, as even more lenient conditions are imposed on the gas conversion, a point can be reached where the recycle ratios for butane and propane are economically excessive and only gaseous olefins can contribute substantial polymerization per-pass yields. This process is inherently limited in flexibility with respect to gaseous feed stock to the extent that the naphtha dictates either its volume or convertibility, but ordinarily presents a favorable picture at high octane levels and with readily convertible or internally produced gas feed.

In another process arrangement to be discussed the gas conversion stock passes first through a thermal polymerization coil, naphtha is admixed, and the blended stream passes through a second coil where joint conversion is effected.

In this modification the reaction conditions set forth above in connection with gas polymerization are applicable to the gas conversion step. The second stage differs from the naphtha-gas conversion step mainly in respect to two features—the incoming gases may contain tar in appreciable amounts and polymer gasoline is present. The severity of the conversion applied to the naphtha needs to be moderated to minimize polymer destruction when the preceding gas conversion has been severe

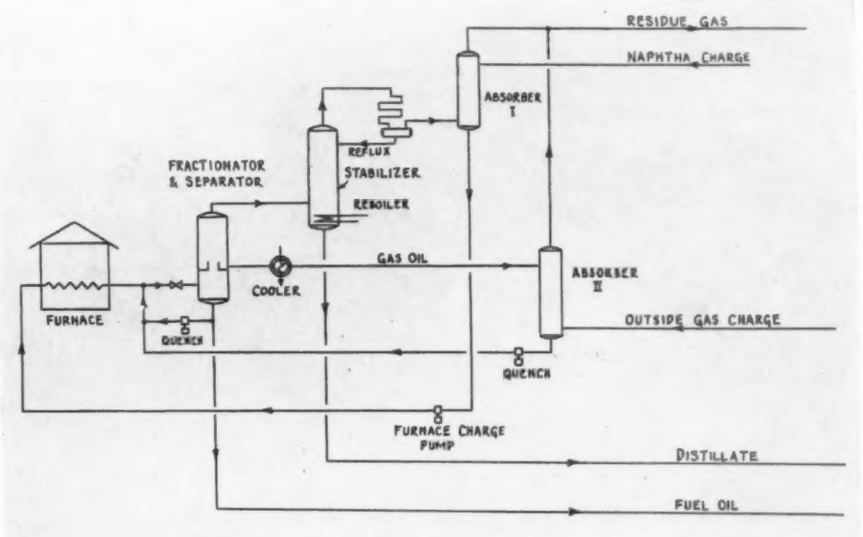
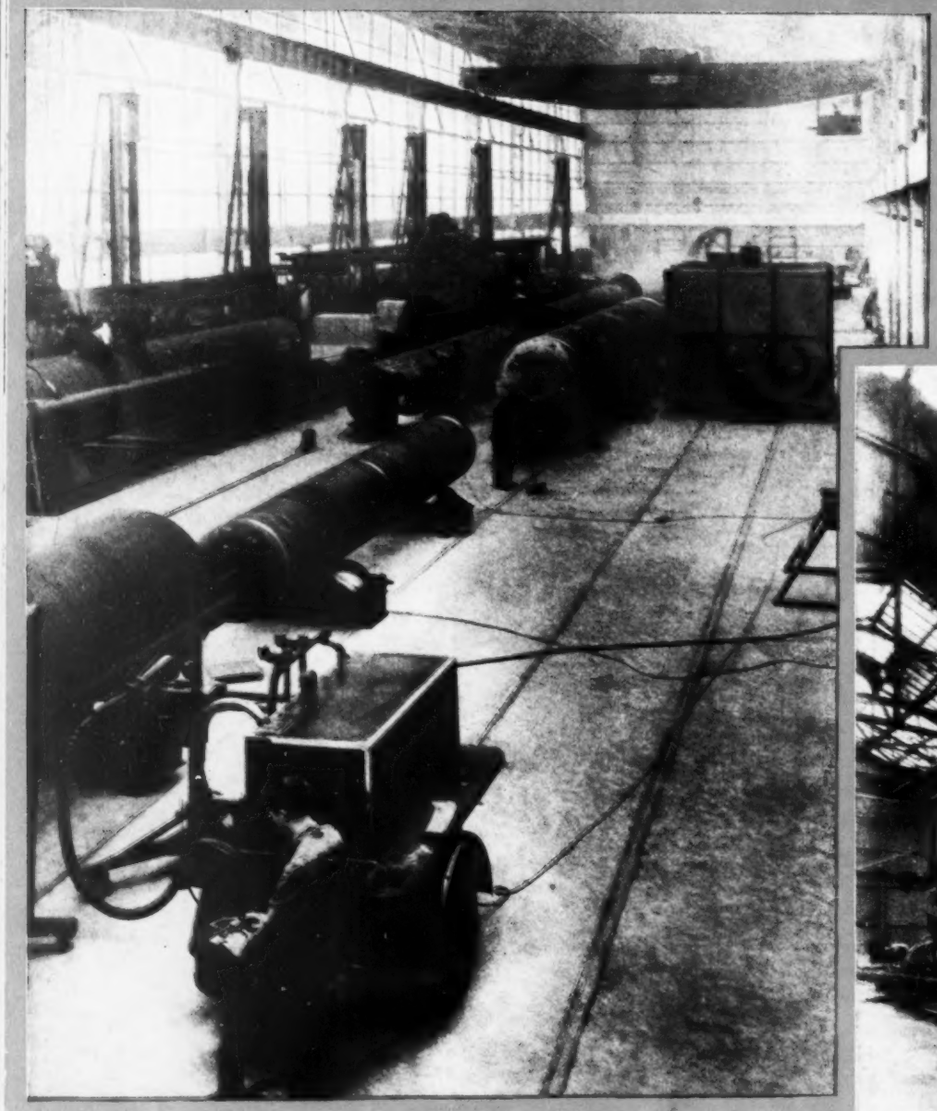


FIG. 4
SCHEMATIC FLOW SHEET
NAPHTHA POLYFORM UNIT

OIL REFINER



The 8,000 ton combined plate bending press and roll shown below is typical of the many special machines designed and made by us for the fabrication of pressure vessels.

Class One Fusion Welded Pressure Vessels in course of construction showing the 400,000 volt X-ray equipment.

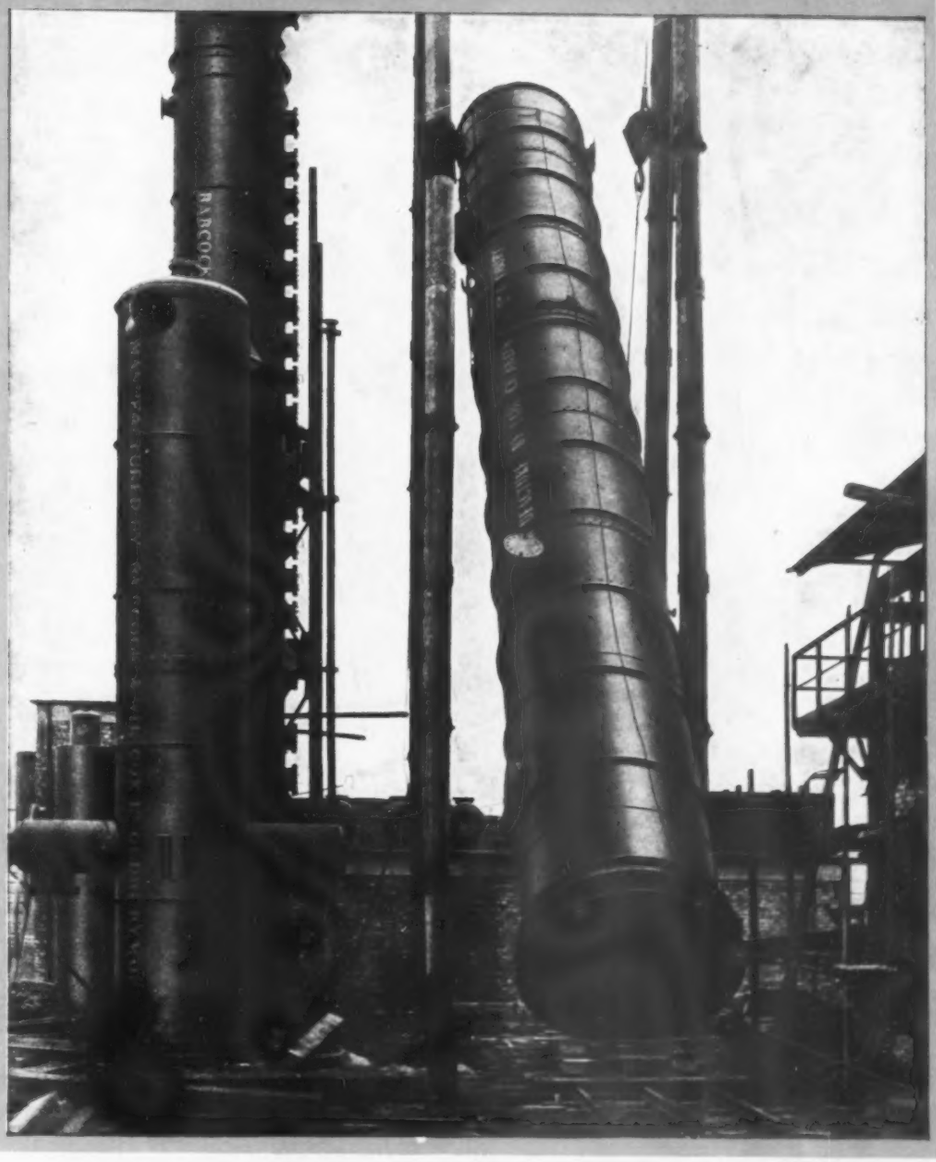
BABCOCK & WILCOX LT

RY EQUIPMENT

ALL Babcock Welded Vessels are manufactured to LLOYD'S, API - ASME, ASME or other recognised codes and are subject to inspection by all the leading insurance companies or other official bodies.

Our Works are particularly well equipped for the construction of reaction chambers, coking chambers, flash chambers, fractionating columns, strippers, evaporators, heat exchangers, condensers, and all vessels included in oil refinery and treatment plants.

Our erection facilities throughout the world are unsurpassed. The illustration to the right shows a vacuum fractionating column being lifted into position, whilst below is a part shipment of oil refinery equipment recently despatched to Latin America.



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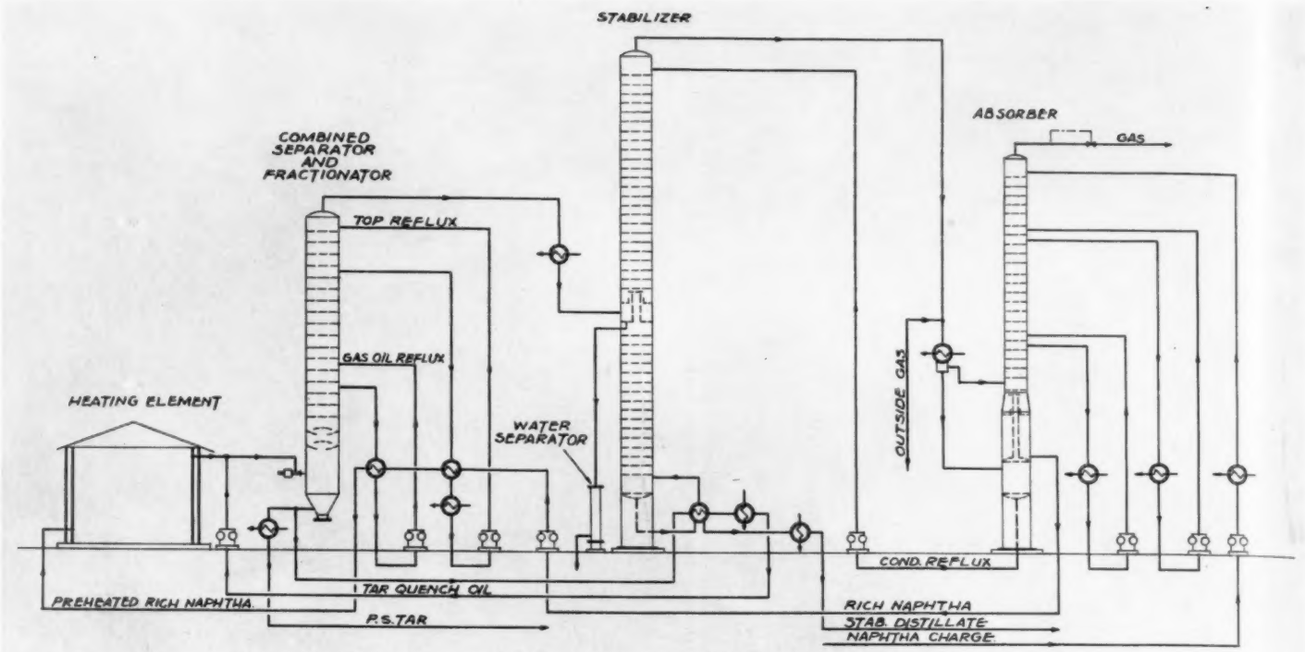


NAPHTHA POLYFORM UNIT

FIG. 5

enough to produce tar, which sets back the coking threshold. Gas tar can be reduced or effectively eliminated by retreating a short way from optimum per-pass yield in the polymerization step; this process then approaches the single stage process.

Desirable conversion conditions in the polymerization step can be selected for any composition of gaseous feed. To produce maximum yields and intermediate octane number, this process allows of moderating independently conversion conditions on the naphtha to any degree, relying on the gas conversion step to convert the gas efficiently.

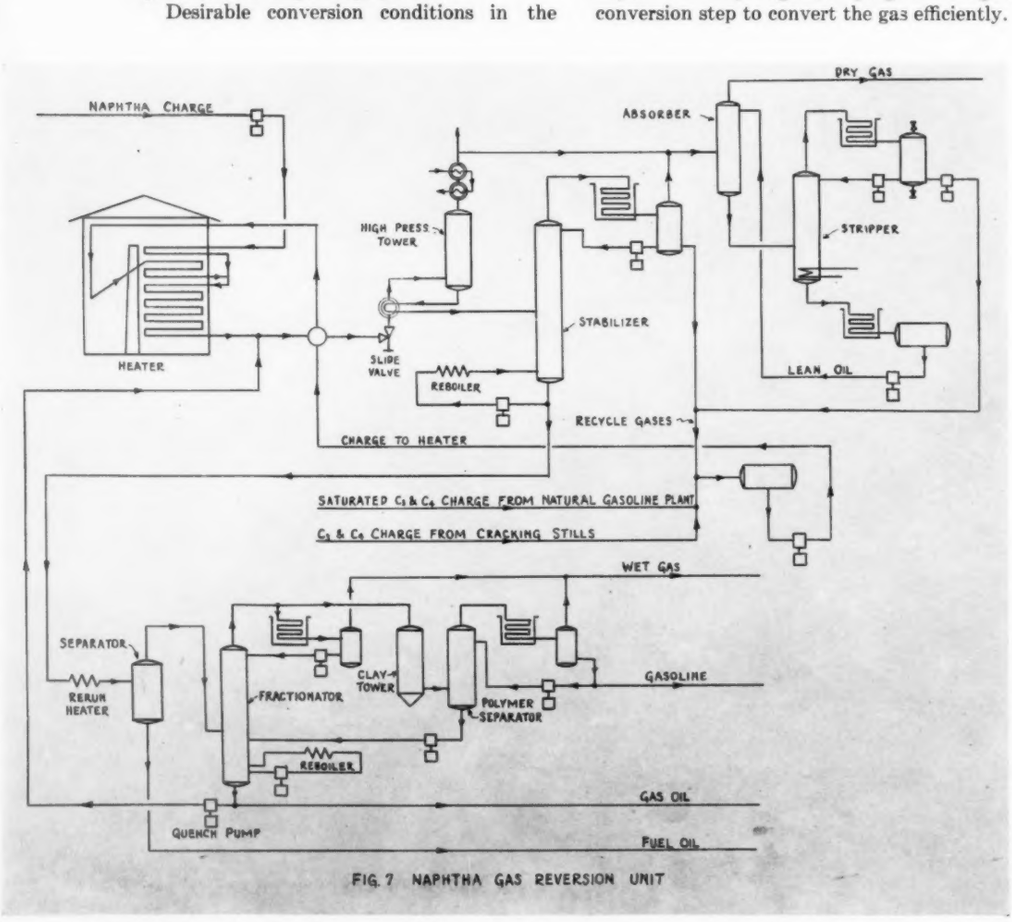


FIG. 7 NAPHTHA GAS REVERSION UNIT

COMMERCIAL APPLICATION

The two processes presented in the paper, namely naphtha gas reversion and naphtha polyforming, are thermal processes in which the naphtha to be reformed is converted into 70 to 80 CFR-ASTM number gasoline in a conversion zone in a mixture with C_3 and C_4 hydrocarbons. The residue gas from these operations is practically free of butane and has a specific gravity varying from .65 to 0.9 depending upon desired propane conversion. The two processes differ in the way the naphtha is introduced into the furnace stream. With the gas reversion process the C_3 and C_4 hydrocarbon furnace charge is first subjected to a partial conversion before the preheated naphtha is injected into this stream. The final conversion, polymerization, and other side reactions of and between the gaseous hydrocarbons and the naphtha take place in a common soaking section. With the naphtha polyform process, a mixture of naphtha and C_3 and C_4 hydrocarbons is preheated and passed together through the entire heater coil. The conversion, polymerization, and other side reactions of and between the gaseous charge and the naphtha progress concurrently. Various modifications and combinations of the foregoing have been adopted commercially and provide efficient utilization of the principles of gas-naphtha conversion. Maximum results have been secured from the various combinations of stocks that have been available. This includes the conversion to gasoline of appreciable quantities of saturated propane and butane.

Figures 3 and 4 represent the basic flow diagrams of these two processes. The rever-

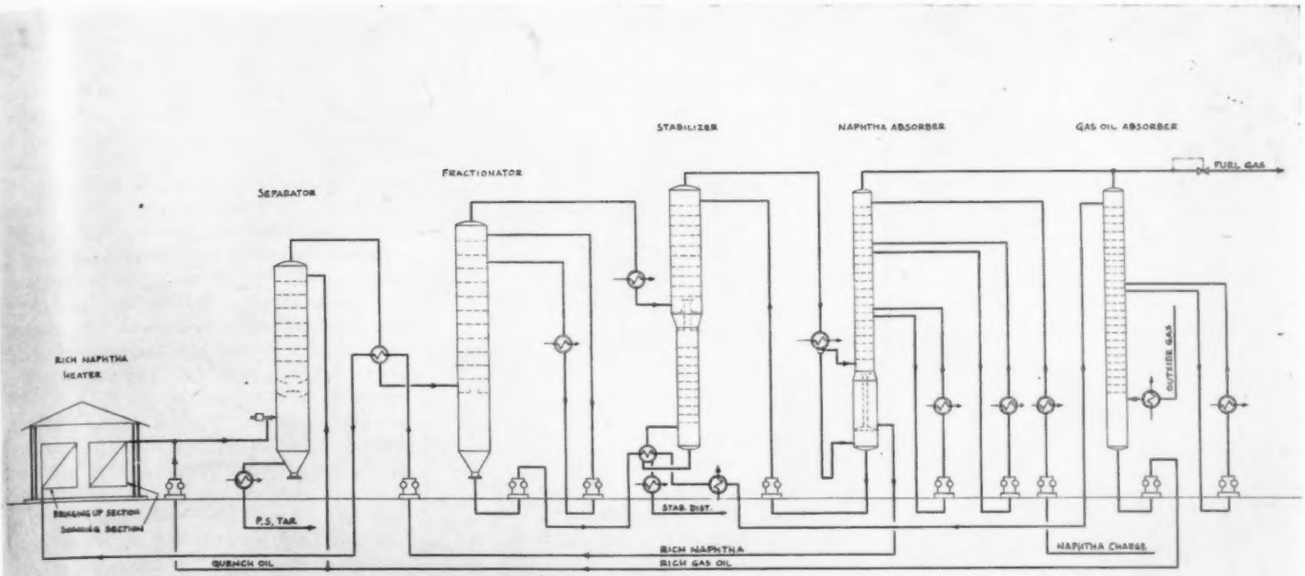


FIGURE 6.
NAPHTHA POLYFORM UNIT
WITH OUTSIDE GAS CHARGE

sion process combines a virgin and a recycle liquefied gas fraction, which is first preheated and then passed through the gas conversion portion of the coil where time-temperature conditions are varied in accordance with the composition of the stock. The preheated naphtha stream is injected into the gaseous stream at the optimum point and the mixture then passes through the remainder of the coil where proper conditions are maintained to effect further gas conversion reactions simultaneously with conversion of the naphtha. Coil outlet products are cooled through charge stock exchangers where quench oil is introduced as a temperature control medium. Subsequent fractionation is arranged to release uncondensible gases in the first step with the recovery of C_3 and C_4 recycle liquid and resultant stabilization of product occuring in the second step. Depending upon the desired degree of propane conversion, recycle liquefied gas may be recovered by absorption from the stabilizer and possibly the high pressure tower residue gas streams. The stabilizer bottoms are separated into gasoline, quench oil and fuel oil by a rerun operation. The absorption and rerun steps may or may not be incorporated in the unit proper.

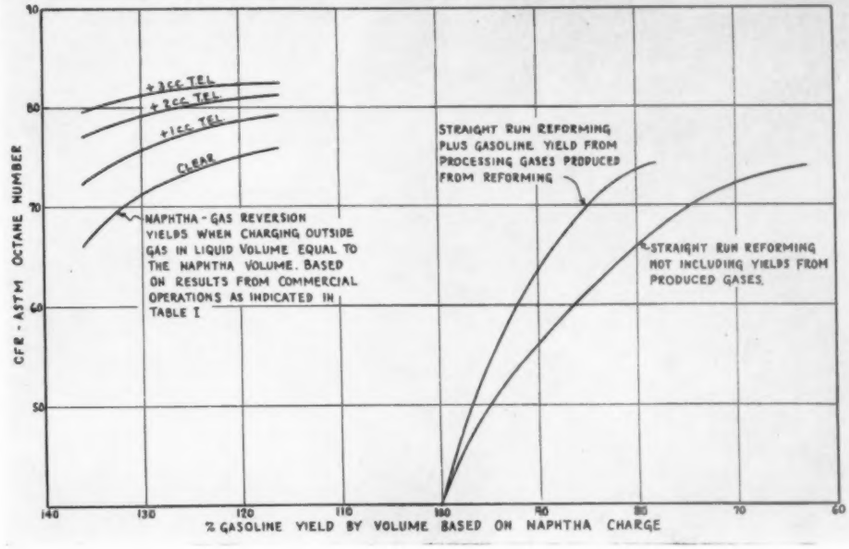
The polyform flow utilizes the naphtha charge as an absorption oil to absorb the uncondensed C_3 and C_4 recycle from the residue gas leaving the stabilizer condenser. The liquefied C_3 and C_4 recycle stock from the stabilizer overhead condenser is mixed with the rich naphtha in the base of the absorber. The rich naphtha from the base of the absorber is preheated and then charged through the furnace. The effluent from the furnace is quenched with fractionator bottoms, flashed to remove tar and then fractionated and stabilized to end point gasoline. The uncondensed residue gas and recycle stock from the stabilizer overhead condenser are the gaseous feed to the absorber.

TABLE IV

Properties of 5%, 10% and 15% Naphtha Cuts and of Total Gasoline Cut from Eastern Venezuela Crude

Percentage on Crude	Naphtha 23.5 to 28.5	Naphtha 18.5 to 28.5	Naphtha 13.5 to 28.5	Total Gasoline 28.5
Gravity: deg. API	45.7	47.9	50.8	60.5
Vapor Pressure at 100 deg. F.	.....	.....	.....	9.6
Aniline Point: deg. F.	126	136	116	120
Acid Heat: deg. F.	3	2	2	3
Sulfur: B—percent	0.05	0.03	0.1	0.01
ASTM Distillation:				
Over Point: deg. F.	315	266	230	101
End Point: deg. F.	465	431	412	412
10 percent at: deg. F.	329	290	258	158
50 percent at: deg. F.	349	311	286	240
90 percent at: deg. F.	409	372	358	342
Octane Numbers:				
CFR-ASTM: Clear	40.9	47.3	49.7	59.9
+1 cc/Gal.—TEL	50.0	56.9	59.6	
+3 cc/Gal.—TEL	60.6	66.1	70.5	
CFR-Research: Clear	46.0	50.1	51.5	
+1 cc/Gal.—TEL	49.8	58.3	60.1	
+3 cc/Gal.—TEL	62.5	70.0	71.3	
Uniontown Road: Clear				
+1 cc/Gal.—TEL		55.5		
+3 cc/Gal.—TEL		67.5		

FIG. 8
YIELD - OCTANE RELATIONSHIPS FOR NAPHTHA - GAS REVERSION AND REFORMING OF STR. RUN GASOLINE FROM GRAY & HUTCHINSON COUNTY, TEXAS CRUDES.


+3CC TEL
+2CC TEL
+1CC TEL
CLEAR
NAPHTHA - GAS REVERSION YIELDS WHEN CHARGING OUTSIDE GAS IN LIQUID VOLUME EQUAL TO THE NAPHTHA VOLUME. BASED ON RESULTS FROM COMMERCIAL OPERATIONS AS INDICATED IN TABLE I
STRAIGHT RUN REFORMING PLUS GASOLINE YIELD FROM PROCESSING GASES PRODUCED FROM REFORMING
STRAIGHT RUN REFORMING NOT INCLUDING YIELDS FROM PRODUCED GASES.
CFR - ASTM OCTANE NUMBER
% GASOLINE YIELD BY VOLUME BASED ON NAPHTHA CHARGE

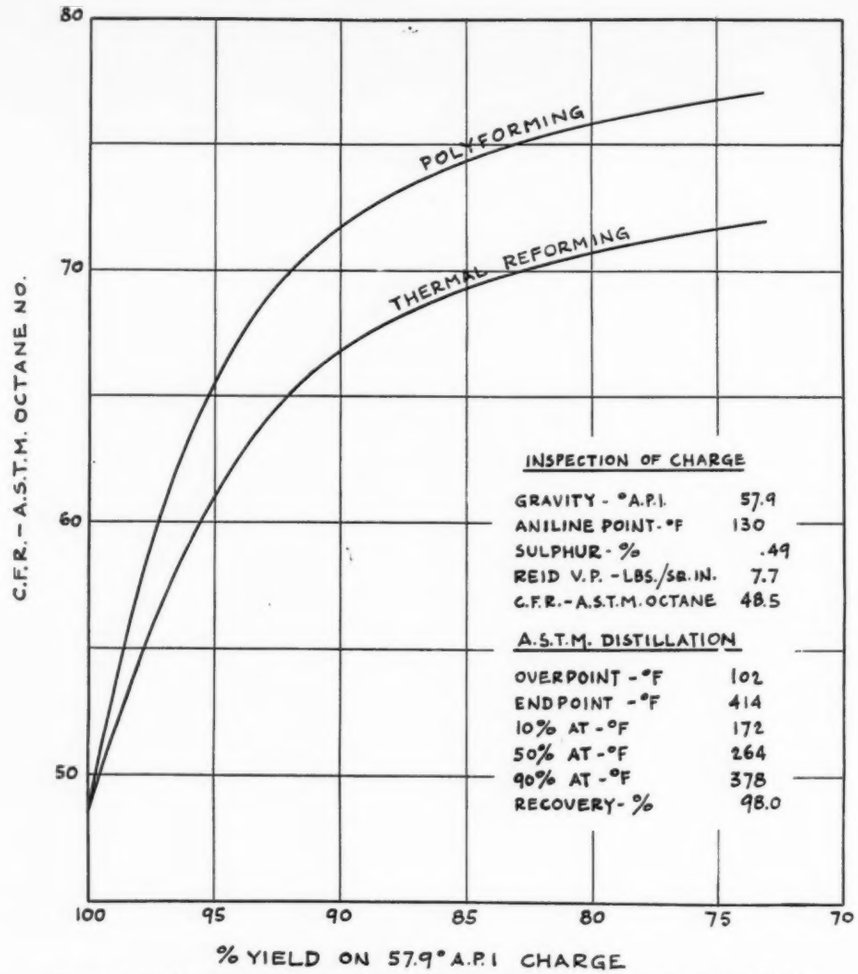


Figure 9: Yield-octane relationship from polyforming and thermal reforming of 57 deg. API West Texas gasoline.

With outside gas feed, a second absorber may be added for absorbing the C_3 and C_4 hydrocarbons from this source. Gas oil from the bottom of the fractionator is used as an absorbing medium. This enriched gas oil is then used as quench for the furnace outlet.

By introducing the gaseous feed to the unit in this manner, any pentane and heavier hydrocarbons in the ouside gas feed are fractionated out in the stabilizer bottoms products and not included in the furnace feed. This prevents a yield loss due to conversion of pentane.

Operating conditions will vary according to the type of operation. For example, the naphtha gas reversion process will normally operate from 1,020 deg. F. to 1,120 deg. F. maximum in the gas conversion section, and 960 deg. F. to 1,060 deg. F. maximum in the reversion section. Outlet pressure on the coil will vary from 1,500 to 2,200 lbs. per sq. in. The naphtha polyform process operates normally between 1,025 deg. F. and 1,125 deg. F. maximum temperature and around 1,000 to 2,000 lbs. per sq. in. outlet pressure.

The equipment employed in both processes is entirely conventional, and, while furnace coils and transfer line exchangers operate at high pressures, no difficulties have been experienced in the design, operation, or maintenance of this equipment. Separating and fractionating equipment is operated at pressures which permit the use of ordinary temperature cooling water for condensation, and also the absorption of recycle from residue gases without resorting to the use of recompression or refrigeration.

The gas reversion and polyform processes described in this paper represent marked technical advances over conventional thermal polymerization and conventional thermal reforming, respectively, yet are adaptable for use in standard process equipment, with comparatively slight modification. This adaptability is in fact one of the outstanding advantages of these new processes. In addition, the operation of these units does not present any problems which have not already been encountered in the average refinery.

These units are also self-contained producing only stabilized distillate, fuel oil, and dry fuel gas, and no auxiliary equipment such as distillate stabilization and gas recovery plants are required. In several cases installation of gas-naphtha conversion units have

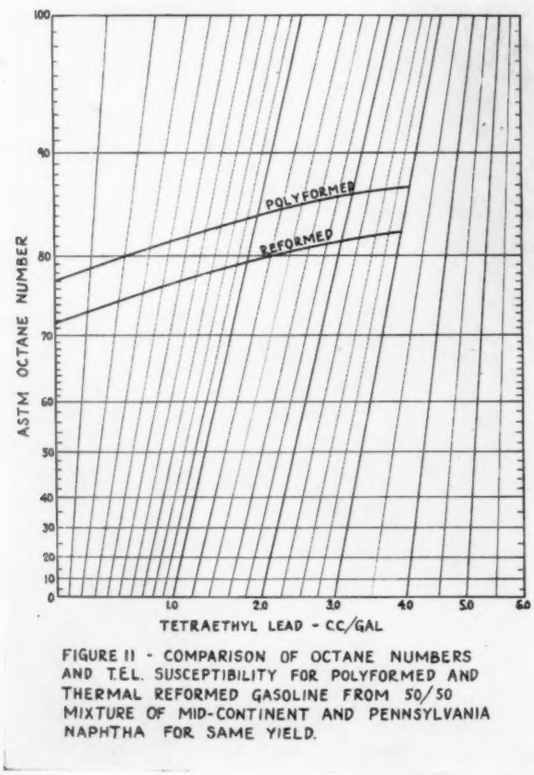


FIGURE II - COMPARISON OF OCTANE NUMBERS AND T.E.L. SUSCEPTIBILITY FOR POLYFORMED AND THERMAL REFORMED GASOLINE FROM 50/50 MIXTURE OF MID-CONTINENT AND PENNSYLVANIA NAPHTHA FOR SAME YIELD.

TABLE V

Comparison of Octane Numbers, Lead Susceptibility, and Blending Values of Naphtha Polyform Gasoline and Distillate from Thermal Polymerization of Propanes and Butanes

Makeup of Blend: Volume Percent											
Polyform Gasoline	100			10	0	25	0	50	0	75	0
Thermal Polymerization Gasoline		100		0	10	0	25	0	50	0	75
Mid-Continent Straight Run Gasoline			100	90	90	75	75	50	50	25	25
Octane No. CFR-ASTM: Clear	76.9	78.1	56.3	58.4	59.9	63.6	63.7	69.5	69.9	73.7	75.0
:+1 cc. TEL/Gal.	81.3	80.4	67.0	68.7	68.3	72.5	71.3	76.6	75.4	79.9	78.8
:+3 cc. TEL/Gal.	83.7	83.3	76.2	77.9	77.6	79.8	79.1	81.8	81.2	83.1	82.2
Octane No., CFR-Research: Clear	87.1	88.4		61.1	60.9	64.7	66.7	74.0	74.0	81.4	81.6
:+1 cc. TEL/Gal.	92.1	92.4	66.3	70.4	70.4	74.0	75.3	80.8	81.5	88.6	87.5
:+3 cc. TEL/Gal.	95.0	95.3	76.3	80.0	78.4	82.4	82.0	87.1	87.0	91.8	91.4
Road Rating: 1940 Plymouth: Clear	81.0	83.5	56.5	58.5	58.5	60.5	61.0	67.0	69.5	75.5	79.5
:+1 cc. TEL/Gal.	86.5	85.5	66.0	67.0	67.0	70.5	69.5	74.5	75.0	82.5	83.0
:+3 cc. TEL/Gal.	90.0	88.0	76.0	79.5	76.5	81.5	78.5	84.5	81.5	87.5	86.5
Gravity: deg. API	61.5	62.9	64.9								
Reid Vapor Pressure, 100 deg. F.: PSI	10.1	10.0	8.2								
Color, Saybolt	+18	+25	+30								
Sulfur, L: percent	0.02	0.12	0.01								
Acid Heat: deg. F	95	85	3								
Aniline Point: deg. F	86	99	137								
Distillation:											
Over Point: deg. F	88	94	95								
End Point: deg. F	378	437	358								
10 percent at: deg. F	119	122	147								
50	197	169	226								
90	328	376	311								
Recovery: percent	97.5	98.5	97.5								

enabled the refinery to shut down existing gas plant operations with resulting savings.

TREATING

Distillate from these operations can be clay treated in conventional manner to 30+ color gasoline. The clay treatment usually results in an increase in CFR-ASTM octane of from 0.5 to 0.7 octane number, a decrease in acid heat and an increase in inhibitor response, inhibitor requirements being reduced approximately 25 to 50 percent, depending upon type of inhibitor used. The yields of clay treated distillate are of the order of 3,000 to 5,000 bbl. per ton of clay depending on sulfur content and other properties of the stock treated. The clay treating is followed by a slight reduction in yield due to production of polymers usually in the range of one-half to two percent.

High octane polyform distillates can be acid treated to reduce acid heat, increase oxygen stability, reduce gum content, improve color stability and to increase load susceptibility.

This type of distillate can be sweetened with conventional processes. Typical results of liquid copper sweetening of gas reversion distillates are shown in Table V. It should be noticed that the octane number is not affected by this method of sweetening.

PROPERTIES

The octane-yield relationship of naphtha gas reversion distillates and naphtha polyform distillates is clearly indicated in Figures 8, 9, and 10.

In Figure 8 is shown the CFR-ASTM octane numbers of gas reversion distillates of various octane numbers ranging from 67.3 to 75.5 both clear and with 1 cc, 2 cc, and 3 cc per gallon of T. E. L.

Figure 9 indicates the octane-yield relationship for a thermal reformed distillate and a polyform distillate from the same stock, a 57.9 deg. API West Texas gasoline with characteristics as shown. This figure indicates the large gain in either yield or octane number which may be obtained by the polyform operation.

Figure 10 illustrates the octane-yield relationship from polyforming naphthas of different boiling ranges from Eastern Venezuela crude. The appreciation from the ASTM to Research and Road Octane Numbers is clearly illustrated by this figure. The CFR Road octanes and the CFR Research octanes of distillates of the same CFR-ASTM octane number from the different types of naphthas are of the same numerical order.

Figure 11 shows the lead susceptibility of a 71.7 octane CFR-ASTM distillate from thermal reforming of a 50-50 mixture of Mid-Continent and Pennsylvania naphthas compared with the lead susceptibility of a 77 octane number CFR-ASTM polyform distillate from the same naphtha charge.

The high octane number, blending value, and general characteristics of gasoline from the thermal polymerization of C_3 and C_4 hydrocarbons are well known. Because naph-

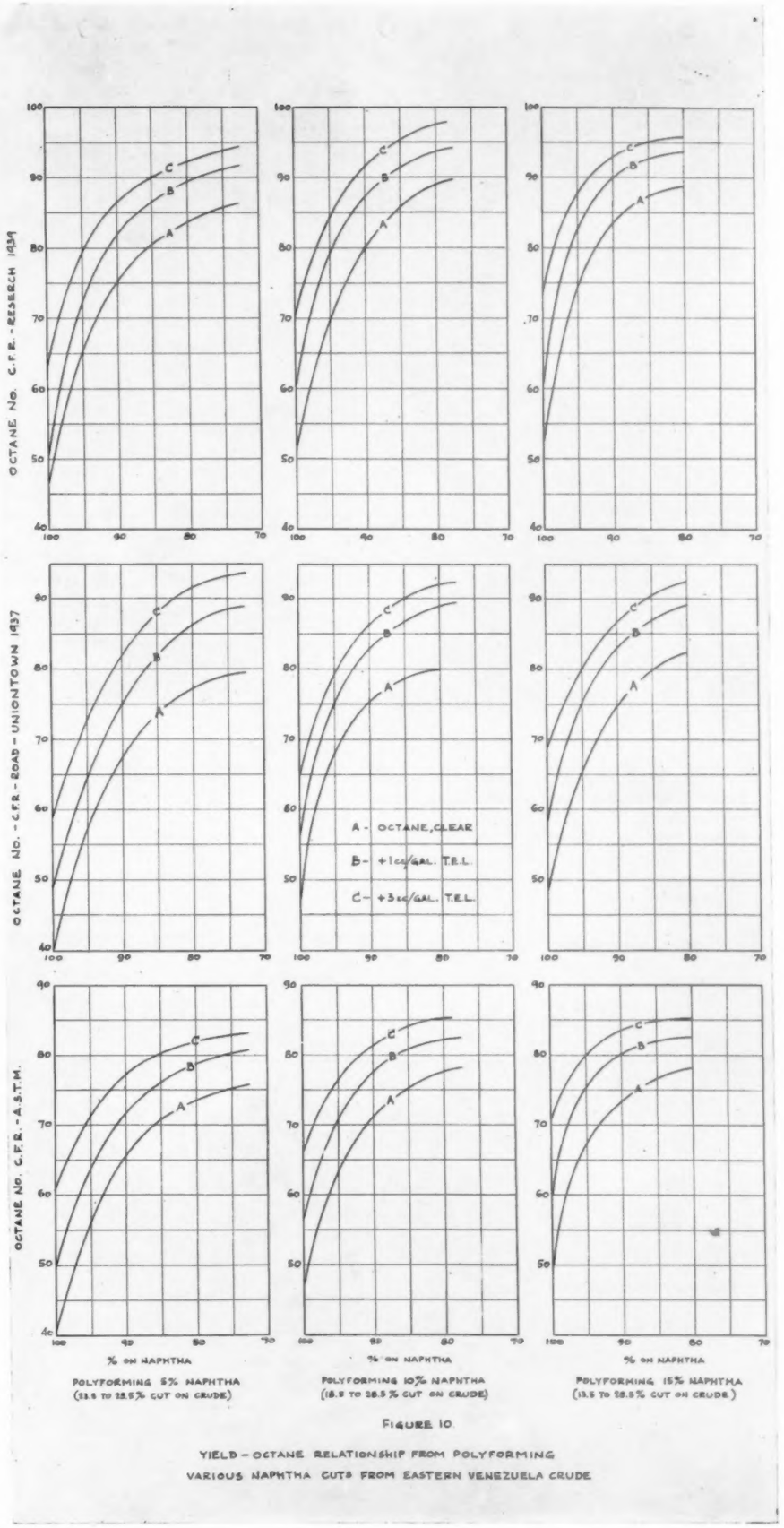

OCTANE NO. C.F.R. - RESEARCH 1939
OCTANE NO. - C.F.R. - ROAD - UNIONTOWN 1937
OCTANE NO. C.F.R. - A.S.T.M.
A - OCTANE, CLEAR
B - +1 cc/GAL. T.E.L.
C - +3 cc/GAL. T.E.L.
% ON NAPHTHA
POLYFORMING 5% NAPHTHA (13.5 TO 28.5% CUT ON CRUDE)
POLYFORMING 10% NAPHTHA (13.5 TO 28.5% CUT ON CRUDE)
POLYFORMING 15% NAPHTHA (13.5 TO 28.5% CUT ON CRUDE)

FIGURE 10

YIELD – OCTANE RELATIONSHIP FROM POLYFORMING VARIOUS NAPHTHA CUTS FROM EASTERN VENEZUELA CRUDE

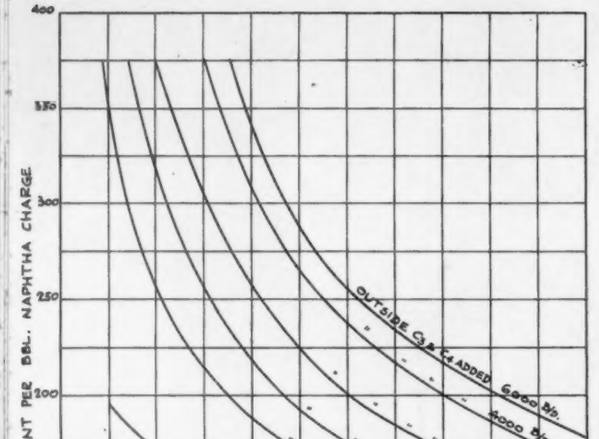
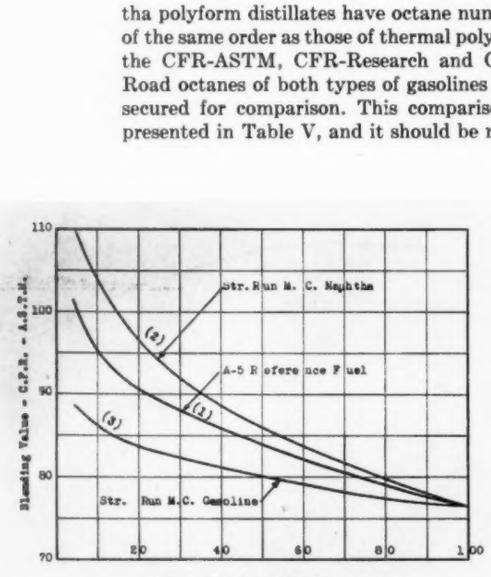


FIGURE 14.
UNIT INVESTMENT COSTS OF NAPHTHA POLYFORM AND GAS REVERSION PLANTS

tha polyform distillates have octane numbers of the same order as those of thermal polymer, the CFR-ASTM, CFR-Research and CFR-Road octanes of both types of gasolines were secured for comparison. This comparison is presented in Table V, and it should be noted



Percent of 76.5 CFR-ASTM Octane No. Polyform Gasoline in Blend

INSPECTION OF BLEND COMPONENTS

	Polyform Gasoline	St. Run Mid-Continent Gasoline	St. Run Mid-Continent Naphtha	A-5 Reference Fuel
Gravity: °API	59.8	69.6	51.5	
Octane No., CFR-ASTM	76.5	60.6	36.0	40.4
Vapor Pressure: PSI	10.6	13.3	2.5	
Distillation, Gasoline				
Over Point: °F.	88	82	144	
End Point: °F.	391	334	474	
10% at: °F.	127	128	234	
50	229	212	328	
90	351	305	420	
Recovery	98	94	99	

Fig. 12

Blending Value of 76.5 C.F.R. - A.S.T.M. Octane No. Polyform Gasoline in: (1) A-5 Reference Fuel; (2) 51.5° A.P.I. Mid-Continent Naphtha, and (3) 69.6° A.P.I. Straight Run Mid-Continent Gasoline.

that there is very little difference in the general characteristics and lead susceptibility of these distillates. This table also indicates that the lead susceptibility is possibly slightly better for the polyform distillate.

Typical blending values of naphtha gas converted gasoline are illustrated in Figure 12 showing the blending value of a 76.5 octane number polyformed distillate in blends with A-5 reference fuel and with a 69.6 deg. API straight run Mid-Continent gasoline with a 51.5 deg. API Mid-Continent naphtha.

The blending value of these distillates with cracked distillates varies with the octane number of the cracked distillates and the proportions of the blends.

In blends with low octane cracked distillates up to 66 CFR-ASTM octane number the polyform gasoline shows a positive blending value. In blends of higher octane cracked distillates the blending value of the polyformed distillate is approximately equal to its octane number. Figure 13 shows blends of a straight run gasoline, a cracked gasoline, and a naphtha polyformed gasoline with inspections as indicated in the figure.

The CFR-ASTM and CFR-Research octane numbers of blends in any desired proportions of the three components can be read directly from the charts. Results are shown for clear octane numbers and with 1.5 cc. T. E. L. per gallon.

OPERATION

Gas reversion has been in full scale operation in the Phillips Petroleum Company refineries for several years and six units are in regular operation representing a total charging capacity of 26,000 bbl. per day consisting of one-half liquefied gas and one-half reversion stocks. Units are readily adjusted for variations in quality or type of charge stocks and can be operated over wide ranges of throughputs. These units operate on approximately 2,100 hour cycles and have a stream time efficiency in excess of 95 percent. All equipment used in these plants is of a commercial nature. Operation, clean-out, and maintenance expenses are comparable with commercial reforming units.

The naphtha polyform process has been in commercial operation for over four years in the various refineries of the Gulf Oil Corporation. In four installations a total charge of 12,000 bbl. per day of naphtha, propane, and butanes are processed. These units operate 2,000 to 2,500 hours between clean-outs. Under construction at present are one 4,000 bbl. per day unit for the Gulf Oil Corporation and one unit for a Gulf Coast refiner by The Lummus Company. This latter unit is designed to charge 9,000 bbl. per day naphtha and 4,000 bbl. per day outside propanes and butanes. Total charging capacity of naphtha-gas conversion units operating and under construction, amounts to 55,000 bbl. per day. Typical flow sheets of reversion and of naphtha polyforming operations are shown in Figures 5, 6 and 7. These flows are more detailed than the fundamental diagrams given in Figures 3 and 4, and are included here for reference purposes.

Yield-octane relationships, including susceptibility to tetraethyl lead additions, from reversion operations on straight run gasoline are given in Figure 8. The curves presented are based on charging an equal volume of liquefied gas for each volume of naphtha charged, and yields are expressed as a percentage of naphtha charge. Inspection of charge and yield products from these operations is shown in Table I. It should be noted that the C_3 and C_4 content of the outside gas charge varies from 72 to 97 percent. Neither this variation nor the ratio of C_3 to C_4 in the charge seem to affect appreciably the general yield-octane curve. Gasoline yields of from 120 to 135 percent and ASTM octanes of from 75.5 to 67.3 are shown. These inspections are taken from full scale commercial operations under normal operating conditions and have been adjusted to equal charge volumes in order that direct comparison of yield-octane relationships may be made. Gasoline inspections shown are on plant treated, copper sweetened material. The reversion charge stock is a straight run gasoline from Gray and Hutchinson Counties, Texas, crude. Figure 8 also shows yield-octane relations for conventional thermal reforming and for reforming plus thermal polymerization of produced gases as a reference. Similar operations on naphthas of different boiling ranges have been conducted with comparable results.

Yield and octane data from polyform operations on different stocks are shown in Figures 9, 10, and 11 and Tables II and III. Figure 9 compares yield and octane when converting a 57.9 API gravity West Texas straight run gasoline by thermal reforming and polyforming.

Figure 10 is a similar relationship based on a more complete series of polyforming runs on naphtha from Eastern Venezuela crude having distillations as indicated in Table IV. The three naphthas are a five percent, a 10 percent, and a 15 percent fraction of the crude. The curves show the CFR-ASTM, CFR-Research, and CFR-1937 Uniontown Road octane numbers of the polyform distillates, clear, and with 1 cc and with 3 cc T. E. L. per gallon. Table II gives complete operating data and charge and product inspections from polyforming separately these naphthas to approximately 76 CFR-ASTM octane number. The yield of the 76 octane distillate is highest from the 15 percent naphtha with the lowest boiling range and decreases as the boiling range of the naphtha is increased. Although the octane numbers of the polyform distillates are approximately the same, the distillation characteristics are quite different. The distillate from the heaviest naphtha has a higher boiling range than the distillate from the lower boiling naphthas. These data show very little difference in the appreciation from ASTM to Road and Research octanes of the different boiling range distillates having the same original octane number.

By suitable variation of operating conditions, the polyform process makes it possible to produce a distillate containing a high aromatic content, even as much as approximately 40 percent.

Properties of Blend Components

	Naphtha Polyform Gas.	Thermal Cr'kd. Gas.	Str. Run Gas.
Grav., °A.P.I.	58.7	62.1	68.1
ASTM Distillation			
Overpoint, °F	90	87	86
Endpoint, °F	414	384	322
Percent distilled at °F			
10	124	125	142
50	257	241	217
90	384	350	287
Recovery, %	97	97	97
Sulfur, %	0.04	0.06	0.05
Octane, CPR-ASTM	75.2	69.0	60.0
Octane, CFR-Res'ch	87.2	78.0	60.0
Octane, CFR-ASTM, and But×1	80.0	76.0	72.5
Octane, CFR—Res'ch and But×1	92.8	85.2	74.4

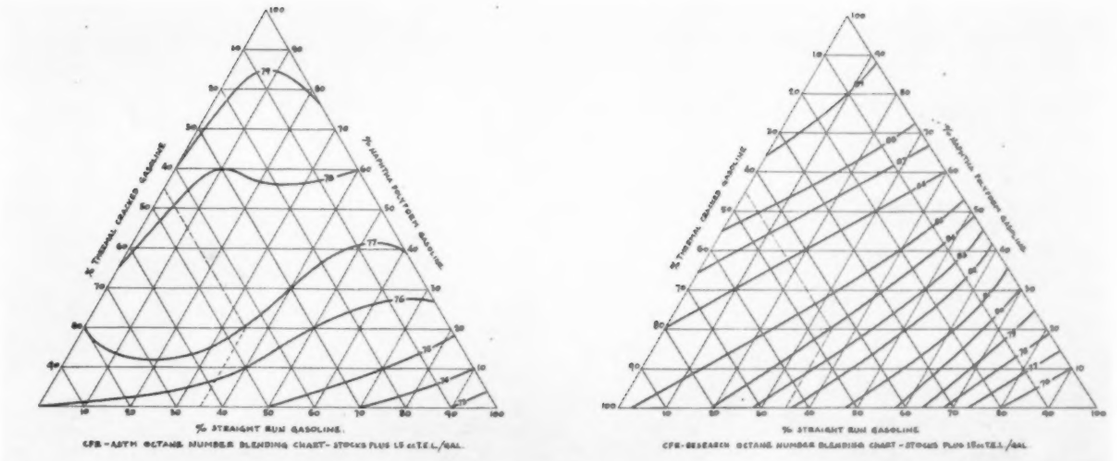

% THERMAL CRACKED GASOLINE
% NAPHTHA POLYFORM GASOLINE
% STRAIGHT RUN GASOLINE
CFR-ASTM OCTANE NUMBER BLENDING CHART- STOCKS PLUS 1.5 cc T.E.L./GAL.
% THERMAL CRACKED GASOLINE
% NAPHTHA POLYFORM GASOLINE
% STRAIGHT RUN GASOLINE
CFR-RESEARCH OCTANE NUMBER BLENDING CHART - STOCKS PLUS 1.5 cc T.E.L./GAL.

FIGURE 13.

BLENDING CHARTS FOR STRAIGHT RUN GASOLINE AND THERMAL CRACKED GASOLINE FROM GAS OIL CRACKING WITH NAPHTHA POLYFORM GASOLINE.

Additional data in this table cover two operations, 5 and 6, on naphtha polyform units with outside gas charge. The variation in yields and in octane number of the products from these two runs are explained by difference in composition and quantity of C_3 and C_4 converted. Yield analysis for these two operations showing estimated source of total gasoline is given in Table III.

ECONOMICS

The commercial application of any new process regardless of improved results obtained must be justified on an economic basis. In evaluating the economics of these processes, the trend to higher octane motor fuels and the conservation of petroleum are important factors.

Gas-naphtha conversion offers improvements in yield and quality over those now being obtained from equivalent volumes of charge, therefore, the economics of this new application are of interest.

While there are numerous variables to be considered in any specific case preliminary studies may be informative. With this in mind two curves are presented from which the approximate investment and operating cost of a commercial unit may be evolved.

Figure 14 shows investment costs for units of varying naphtha-gas charge capacities based on a gas composition containing approximately equal volumes of propanes and butanes.

Figure 15 shows direct operating costs for varying naphtha-gas charge capacities.

The following assumptions have been used in preparing the curves:

Material specifications based on processing non-corrosive stocks and representing construction costs based on labor rates prevailing in the Mid-Continent area.

Utility Costs Basis

Fuel per barrel	$0.60
Steam per thousand pounds	0.25
Electric Power per Kilowatt Hour	0.005
Cooling Water per thousand gallons	0.015
Labor per man hour	1.00

An average figure for maintenance, cleaning, inspection, and repairs based on existing commercial operations has been included in the data from which Figure 15 was plotted. Table VII presents utilities consumption for two commercial polyform and gas reversion units.

To illustrate the use of Figures 14 and 15, a plant processing 4,000 bbl. per day of naphtha and 2,000 bbl. per day of outside propanes and butanes will cost erected $257.60 per bbl. of naphtha charged, or $1,028,000, and the direct operating cost will be $0.16 per bbl. of naphtha charged or $640.00 per day.

Although difficult to evaluate, a polyform or gas reversion plant raises the upper octane limit of the overall gasoline production and also improves the road performance.

Current realizations from naphtha gas reversion and naphtha polyform units show that the payout period on the investment for these processes is from 1 to 3 years due to increased gasoline yield and saving in tetraethyl lead. This economic picture, plus the fact that either of these operations are carried out in a single unit makes these processes attractive to the refining industry for the production of high yields of higher level octane motor fuels.

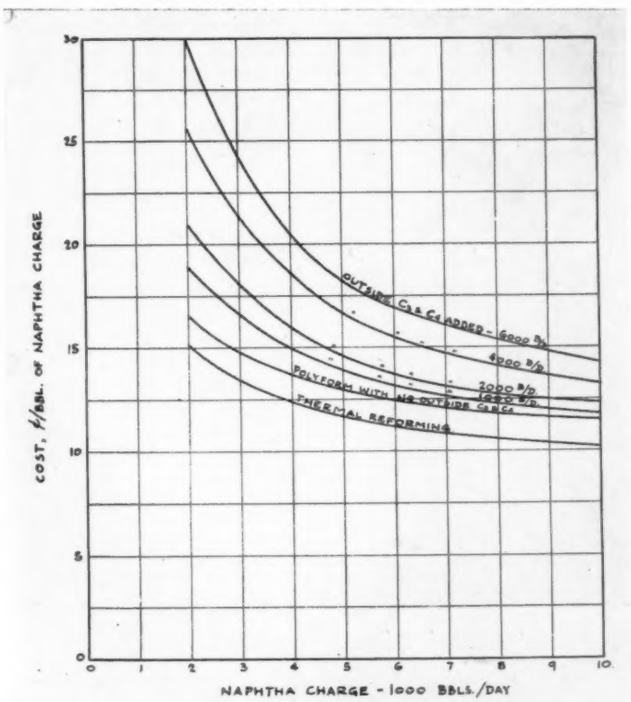

COST, ¢/BBL. OF NAPHTHA CHARGE
OUTSIDE C3 & C4 ADDED - 6000 B/D
4000 B/D
2000 B/D
POLYFORM WITH NO OUTSIDE C3 & C4
THERMAL REFORMING
NAPHTHA CHARGE - 1000 BBLS./DAY

FIGURE 15.

DIRECT OPERATING COSTS OF NAPHTHA POLYFORM AND GAS REVERSION UNITS.

TABLE VII

Operating Utilities
Based on Commercial Operations

Operation:	1	2
Charge:		
Naphtha, B/D	1,200	4,000
Outside Gas, B/D	1,500	.....
Total, B/D	2,700	4,000
Temperatures, deg. F:		
Charge to Furnace	530	475
Furnace outlet	1,015	1,070
Pressures, Lbs./Sq. In.:		
Charge to Furnace	2,700	1,250
Furnace Outlet	1,900	1,000
Fractionating System	300-400	350-370
Utilities:		
Per Barrel Naphtha Charged:		
Electric Power, KWH	7.50	1.03
Steam, Lbs.	2.0	57.6
Fuel, Barrels	0.176	0.072
Water (25 deg. F. rise), Gals.	1,680	1,940
Clay, lbs.	.....	0.52
Labor, men per shift	2	3

FURFURAL Refining of Pennsylvania Oils for Severe Conditions

By F. T. Mertens
Design-Engineer
Foster Wheeler Corporation

FOR many years, conventional refining methods have enabled the refiners of Pennsylvania crude oil to manufacture the best lubricants obtainable in the United States. This was like calling the New York Yankee baseball team the "World Champions," since the champion of this country automatically became the champion of the world. So it has been in the case of fine lubricating oils, with practically the whole world looking to the United States for motor and industrial oils to keep their wheels turning.

During recent years, however, automobile and aviation motor manufacturers have been using higher compression ratios, higher engine speeds, closer clearances—all of these developments contributing to greatly increased power output. Unfortunately for the lubricants, these improvements have imposed much more severe duties on lubrication and the former conventional refining methods are no longer satisfactory to meet all these requirements, either physically or economically. The best oil now must have superior over-all performance characteristics—not merely a good viscosity index or high resistance to sludge formation. Modern lubricants must have all eight of the following properties:

1. High film strength
2. High resistance to oxidation
3. Freedom from sludge formation in engine.
4. No bearing corrosion.
5. Low oil consumption in engine.
6. High viscosity index.
7. Low pour test (wax-free).
8. Low increase in viscosity during use.

To produce such a "super-lubricant," a satisfactory crude must be selected as a base and here the Pennsylvania refiner has a definite advantage—but he cannot stop at this point. A suitable selective solvent refining process must be used to obtain these desired properties and thus attract the consumer's dollar.

Recognizing the difficulties to be encountered with expanding use of higher output engines, one of the leading Pennsylvania refiners conducted a careful investigation to determine how his oils could be improved. The study resulted in the installation of two furfural refining units, using a process that has been established throughout the refining industry as highly satisfactory and economical for this purpose. Over-all quality of the oils has been materially improved, as well as reducing the costs of subsequent filtering operations.

The process is based on the use of furfural, manufactured from oat hulls which were formerly regarded as agricultural waste. Furfural is an aldehyde that acts as a selective solvent, removing certain undesirable portions of the oil, namely, the aromatic and olefinic hydrocarbons, and leaving unchanged the more paraffinic, or desirable constituents. Its properties as a refining agent have been known since 1923 and it was first applied commercially in 1933 at the Indian Refining Company plant at Lawrenceville, Illinois. This plant has been in constant operation since that time. The use of furfural has extended to numerous refineries having a total average daily capacity of over 30,000 bbl. The solvent is relatively non-poisonous, inexpensive, stable, showing negligible loss over long periods of operation and the supply is practically unlimited. Both installations and operating costs of the process are notably low.

The specifications of furfural, as furnished by the Quaker Oats Company, are shown in the accompanying table.

Specific gravity 20/20 deg. C. (Min.)	1.158
Engler distillation	
Temperature end of 1st cc. (Min.) deg. F.	300
Temperature at end point (Max.) deg. F.	335
Recovery (Min.) percent	98.5
Residue (Max.) percent	0.9
Loss (Max.) percent	0.9
Mineral acidity (Max.)	None
Sulfates ($BaSO_4$ method) (Max.)	None
Ash (Max.) percent	0.006
Organic acidity (calc. as acetic acid) (Max.) percent	0.12
Water (by distillation) (Max.) percent	0.2

The simplified flow-sheet is typical of the two Pennsylvania installations mentioned which consist of the following main operating units:

1. Vertical counter-flow extraction tower with essential shell-and-tube heat exchanger equipment to treat continuously oil with the solvent at the desired controlled flow rates and temperatures. Refined oil (raffinate) containing a small amount of the solvent is drawn off at the top of the column and the extract containing the undesirable constituents dissolved in furfural is removed at the bottom. The tower also includes surge capacity for storing raffinate and extract solutions before they are discharged to the respective recovery sections.
2. Solvent - from - raffinate recovery unit in which the solvent is freed by distillation under vacuum, and subsequent steam stripping removes any remaining traces of furfural from the treated oil.
3. Solvent - from - extract recovery unit including vacuum steam stripper as above.
4. Solvent - from - water recovery system including separator and surge tank with two fractionating towers in order to separate the water introduced by the steam strippers and recover the unchanged solvent for treating new charges of oil.

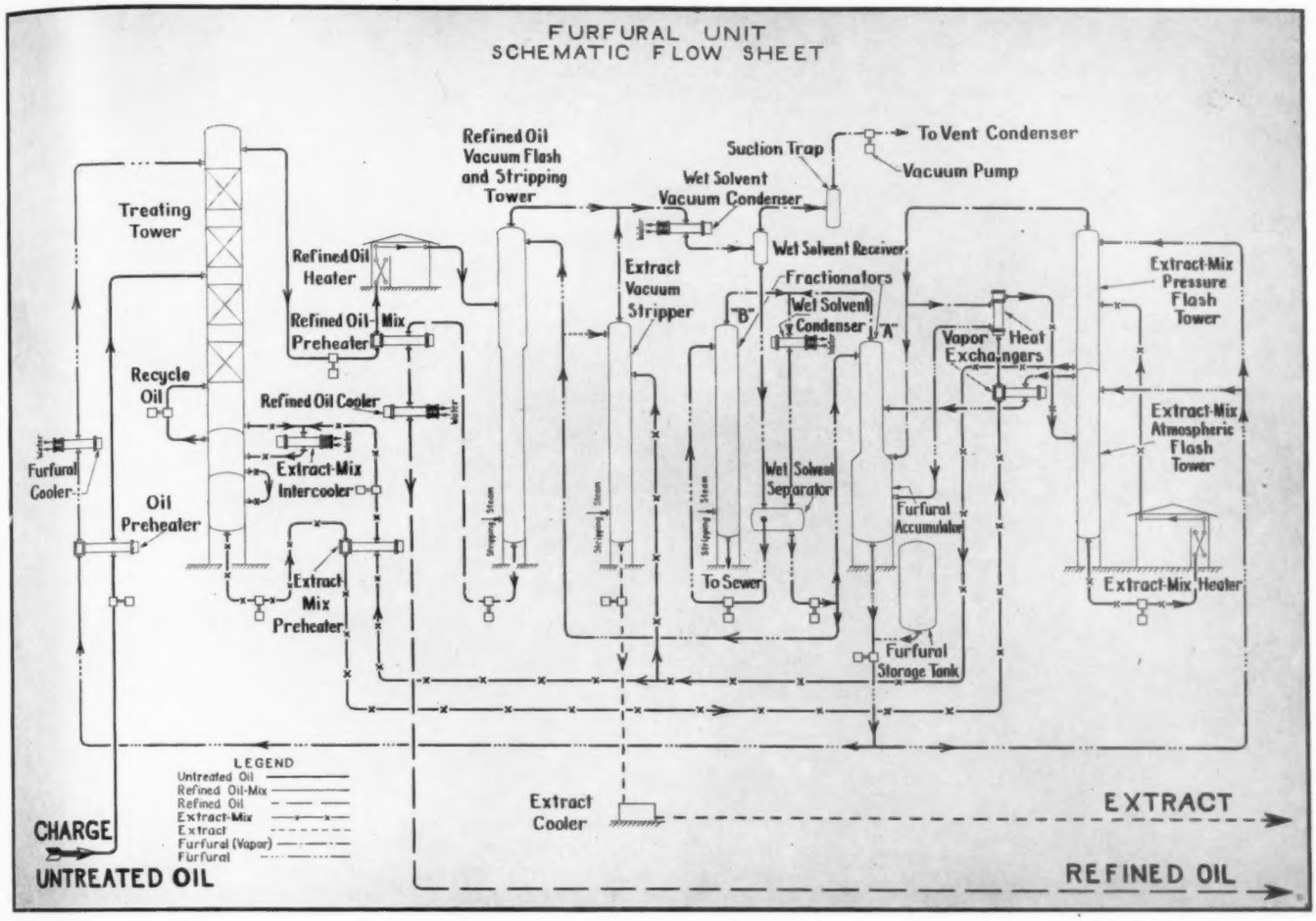
A 680 bbl. per day furfural unit nearing completion.

Untreated oil is preheated in a heat exchanger to 140 deg. F.-180 deg. F. by hot furfural and charged to the middle of the treating section of the extraction tower which is packed with Raschig rings. Furfural at a temperature ranging between 200 deg. and 280 deg. F. is charged to the top of the tower just below the raffinate-mix surge space. By maintaining a substantial temperature gradient across the treating section, the quality and yield of the refined oil is held at its optimum point for any given solvent dosage and the counter-current liquid-to-liquid extraction process proceeds with the furfural flowing downward through the oil-filled packing. This type of tower requires low quantities of solvent and oil in the system; low investment, operating and maintenance costs, and affords simplicity of operation and control.

Refined oil solution, containing only a small percentage of furfural, collects at the top of the tower and is pumped through a heat exchanger and direct-fired heater to the vacuum flash and stripping tower where all traces of the solvent are removed. The finished oil then flows to storage for filtering and final preparation before being marketed as high grade lubricating oil.

The extract solution contains most of the furfural together with undesirable components removed from the charge oil. It flows down through the recycle and surge sections of the treating tower. From here it is pumped through heat exchangers to the atmospheric flash column where between 30 and 40 percent of the solvent contained in the extract mixture is vaporized. The flash solution is then pumped through a direct-fired heater to a pressure flash section in which most of the remaining furfural is vaporized. From the pressure flash tower, the extract, with the small portion of furfural still in equilibrium, flows to a vacuum steam stripper where all traces of furfural are recovered. The stripped extract, which has the appearance of asphaltic material, is then pumped through a cooler to storage where it may be used as heavy fuel oil in the refinery.

The recovery of furfural from condensate water is a simple process since furfural and water form a constant boiler mixture having a lower boiling point than either pure furfural or water. It is therefore relatively easy to



effect complete recovery of the furfural from any furfural-water mix using the two fractionating columns. This C. B. M. is collected in the separator where it divides into two layers. The lower layer, rich in furfural, is charged to one fractionator (A) where water is removed using furfural vapors as a stripping agent and the pure furfural accumulates in the surge section of reservoir at the base. The upper layer, mostly water, is charged to the second column (B) where open steam strips the furfural from the water. The remaining furfural-free water is dumped to the sewer.

To illustrate how the furfural process fits into the refinery procedure—under the former so-called conventional method, wax distillate would be dewaxed by cold-pressing, reduced in a rerum still to the viscosity of neutral oil, and clay-treated to the desired color either by percolation or contacting, without any further attempt to improve stability or resistance to oxidation. Cylinder stock bottoms were clay-treated, centrifuge-dewaxed to the desired pour point, and processed in reducing units to remove dilution naphtha.

When the furfural process is used, however, the crude charge is again distilled into wax distillate and cylinder stock bottoms. If no solvent-dewaxing is employed, the wax distillate is processed as above with the furfural process following the rerum operation (viscosity reduction) and preceding the clay finishing. Cylinder stock bottoms are first furfural refined, then clay treated, centrifuge dewaxed and reduced as before. If a solvent dewaxing process is included, a viscous wax distillate is produced at the still and finished to neutral oil specifications without further reduction. This distillate is furfural refined, solvent dewaxed and clay finished; the corresponding cylinder stock is treated likewise.

The following charge and product tests are typical of results being obtained:

0 Deg. Pour Dewaxed Penna. 600 Stock Charge Treated with 200 percent by Volume of Furfural

	Charge	Extract	Raffinate	Filtered Raffinate
Yield, percent by volume	100.0	9.9	90.1	.....
Gravity, A. P. I.	25.0	8.7	27.0	27.5
SSU Vis. @ 100° F.	3210	.....	2490	2097
SSU Vis. @ 210° F.	172.0	.....	156.8	142.1
Viscosity Index	94.4	.....	101.5	102.6
Carbon Residue, percent	2.42	.....	1.58	1.00
Pour, deg. F.	0	0	0	0

Bright stock filtered to color of 2 Tag. Robinson.
Percolation filter yield increase 50 percent.

Low Pour Pennsylvania Natural Charge Treated with 150 percent by Volume of Furfural

	Charge	Extract	Raffinate
Yield, percent by volume	100.0	10.2	89.8
Gravity, A. P. I.	29.9	10.1	32.5
SSU Vis. @ 100° F.	177.6	2926	156.4
SSU Vis. @ 210° F.	43.9	75.5	43.3
Viscosity Index	93.5	—214	109.6
Color, N. P. A.	4½L	Black	1½D
Pour, Deg. F.	—10	.....	—10

Neutral oils obtained from Pennsylvania distillates are known to be relatively unstable, when produced by conventional refining methods. The degree of stability is not reflected in the above test results either on the charge or raffinate. Such characteristics can be determined only by engine block tests or road tests. However, the effectiveness of the furfural refining process has been amply demonstrated by numerous tests of both types, which indicate materially increased stability and decreased sludging tendency in furfural refined oils. Hence, these oils make it possible to keep an engine free from lacquer and sludge formation over long periods of time.

From the point of view of refinery operation, the use of furfural has reduced percolation filter costs by increasing the filter yields from 50 to 300 percent. Undesirable constituents are eliminated from the oil with the rejection of only a small percentage of the total charge stock, and without hindering subsequent dewaxing operations. From the point of view of the lubricant market—oils from crude sources other than Pennsylvania have been so improved by solvent treatment as to materially reduce the natural advantage enjoyed by Pennsylvania oils in the past. Continued leadership of the modern market by Pennsylvania oils can be assured in the future only by the use of effective solvent refining.

Canada's Sub-Arctic Refinery

By Richard Finnie
Author of "Lure of the North"

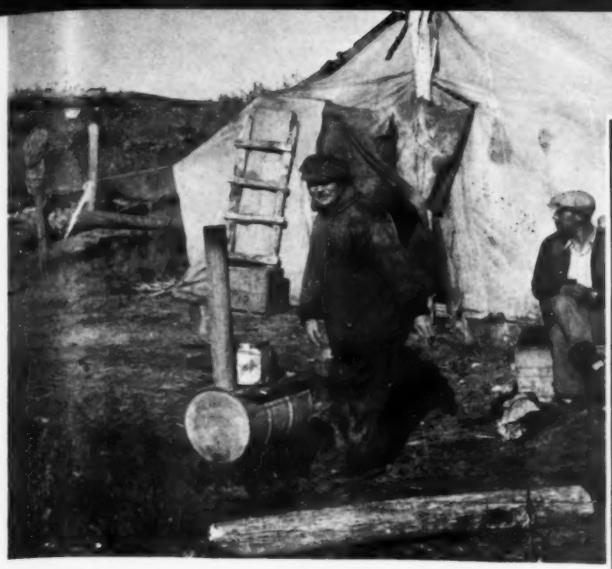
"GOLD has been said to exist in certain of the barren grounds. Silver on the Upper Liard and Peace Rivers, copper upon the Coppermine River, which may be connected with an eastern arm of Great Bear Lake by a tramway of 40 miles, iron, graphite, ochre, brick and pottery clay, mica, gypsum, lime, and [in the Mackenzie District] the petroleum area is so extensive as to justify the belief that eventually it will supply the larger part of this continent and be shipped from Churchill or some more northern Hudson Bay port to England. . . . "

That is a quotation from the report of a special committee of the Canadian Senate, appointed to investigate the natural resources of the Mackenzie Basin, in 1887-88. It shows that at least a few people in Canada were becoming enthusiastic over the mineralization of the Far North more than a half-century ago—and with good reason, as later events have proved, albeit the prophecy hasn't quite been fulfilled yet.

Knowledge of the existence of minerals in the Canadian Arctic and sub-Arctic goes back to Elizabethan days, when Martin Frobisher carried shiploads of pyrites from Baffin Island to England in the fond supposition that it was gold; copper was found by Samuel Hearne near the mouth of the Coppermine River in the Arctic in 1771; and in 1789, exploring the great river that now bears his name, Alexander Mackenzie noted coal seams a-fire.

Somewhere in the neighborhood of the Arctic Circle, Mackenzie also wrote in his journal: "We passed a small river, on each side of which the natives and Esquimaux collect flint. The bank is an high, steep, and soft rock, variegated with red, green, and yellow hues. From the continual dripping of water, parts of it frequently fall and break into small stony flakes like slate, but not so hard. Among them are found pieces of *Petrolium*, which bears a resemblance to yellow wax, but is more friable. . . . "

But Alexander Mackenzie and his successors for many years to come were not prospectors; their main job was to open up a new territory for the fur trade. Finally, in 1897-98, some of the adventurers who took part in the Klondike gold rush went to the Yukon via the Mackenzie. They paused here and there along the Mackenzie and its tributaries to stake claims, but most of those claims were never even recorded. In 1901 a young geologist accompanied by a fur trader's son named Charles Camsell (destined to become Deputy Minister of the Federal Department of Mines and Resources) explored the shore of Great Bear Lake. They were wind-bound for several days in Echo Bay, at the eastern side of the lake, about which the geologist, James Mackintosh Bell, observed: "The variegated mineral staining—red, black, pink, white, and green—gave scintillating reflections in the deep, transparent water, and suggested a locality to lure the prospector." Dr. Bell lived long enough to hear about an amazing sequel to his visit to Echo Bay, for nineteen years afterwards a shrewd prospector staked claims there and today those claims support the richest pitchblende mine in the world. It was



this discovery, Gilbert LaBine's discovery, that provided the impetus needed to develop the oil wells of the Mackenzie River.

Although the presence of oil as well as coal along the banks of the Mackenzie had become known among explorers, traders, missionaries and the mounted police since Alexander Mackenzie's time, the remoteness of the region stood in the way of any serious investigation until 1914. In that year Imperial Oil Limited (Canadian subsidiary of Standard Oil of New Jersey) sent representatives down the river. They promptly staked claims at several points, but their attention was particularly attracted to the right bank about fifty miles below the old trading post of Fort Norman. The outbreak of the first World War caused their reports to be shelved.

The distance from Edmonton—most northerly city in Canada—to Fort Norman is nearly 1,500 miles by water, and the building of a railway was (and is) not feasible for a long time to come; and although by 1919 the Turner Valley gushers were beginning to serve Alberta, there was an every growing demand for oil in Canada, so Imperial Oil Limited planned for the development of its Fort Norman claims, with perhaps a view to running a pipeline to the south.

Opposite, Eldorado camp on Echo Bay, Great Bear Lake. A short distance south of the Arctic Circle, this is the world's richest pitchblende mine. Above, camp stove made from small gasoline drum from the Fort Norman refinery. Right, Canadian Geographical Society map of the District of Mackenzie. Below, drilling rig and log buildings of Discovery Well camp on the Mackenzie, 53 miles below Fort Norman as it appeared in July, 1930.

The company sent north two drilling crews to test for oil. The transporting of their heavy machinery and other equipment was a pioneering task. The Peace River route was followed and the whole outfit had to be moved across a four-mile portage at Vermillion Chutes and the 16-miles portage between Fitzgerald and Fort Smith. (Nowadays the route is from Edmonton 300 miles to Waterways by rail, then down the Athabasca and Slave Rivers to Fitzgerald.) Special scows and motor boats were constructed and the first tractors ever seen in the Northwest Territories lugged the equipment into Fort Smith, just beyond the 60th parallel of

latitude which is the borderline between Alberta and the Territories. Boats and scows were launched again below the Rapids of the Drowned, continuing down the Slave River to Great Slave Lake and thence northward down the Mackenzie.

The drillers established their camp on the claims below Fort Norman and spent the winter of 1919-20 there. That summer they struck oil. Reports that they had commercial production reached Edmonton in the fall.

At a depth of 85 ft. oil began to seep into the hole and from there down it increased. At 785 ft., August 24, the well spouted a six-inch stream of oil to a height of 75 ft. above the derrick floor for about ten minutes, after which it was capped. The flow was estimated at 600 bbl.

Above, the upper of two 18,000 gal. tanks, eight miles apart above and below the Great Bear River Rapids; portage pipeline comes in from the right. Left, the sub-arctic gold mining town of Yellowknife, established 1936, with petroleum storage from Fort Norman in foreground.

The newspaper publicity precipitated a stampede as between 300 and 500 men trekked northward from Edmonton, including employees of Imperial Oil and various small syndicates. Some of the independent oil-seekers were as colorful as old-time Klondike characters—from J. Wada, the Japanese who won and lost fortunes at poker, to Jim Darwish, the Syrian who settled down in the north as a fur trader.

Claims were staked everywhere up and down the Mackenzie around the Imperial Oil property. Those of individuals were snapped up by syndicates, and eventually all of them that showed any promise were acquired by Imperial Oil.

It was the Norman strike that brought the first airplanes as well as the first tractors into the Northwest Territories. Imperial Oil bought two Junkers monoplanes with the intention of accelerating communications with its northern holdings. In the spring of 1921, with Pilots Fullerton and Gorman, mechanics and several passengers, they flew as far as Fort Simpson, 270 miles short of their goal. Both planes were damaged and a smashed propeller was replaced by one fashioned on the spot from an oak sleigh board and moose glue. The following autumn another try was made, which succeeded. It was not until 1928, however, that commercial flying became a reality in the Mackenzie District, and then it revolutionized the lives of the inhabitants and made large-scale development possible.

Imperial Oil drilled two additional holes during 1921 in the vicinity of its discovery well, less than 100 miles south of the Arctic

All photographs used to illustrate this article were taken by the author, Richard Finnie.

Circle. One on Bear Island was bored to a depth of 2,080 ft. A showing of oil was obtained at 1,945 ft. and further indications of oil and gas at 1,975 ft., below which there was a quantity of salt water. The other well, on the west bank, was bored to 3,057 ft. in limestone, but without a satisfactory result. During the same period a hole was drilled to a depth of 1,806 ft. at Windy Point on the north shore of Great Slave Lake. It proved dry and was abandoned.

In 1922 the discovery well was deepened to 951 ft., when a flow of 60 to 70 bbl. per day was recorded. A fourth hole was begun up stream near the Fort, but owing to a shortage of drillers it was sunk to only 500 ft. and capped.

The Fort Norman Oil Company secured locations on the right bank of the Mackenzie about six miles below Imperial Oil's discovery well and in 1921 drilled to 1,512 ft. Oil was found at 305 ft. and a flow of gas estimated at 300,000 cu. ft. at 385 to 500 ft. The well was capped and operations were suspended.

The White Beaver Oil Company, during the winter of 1921-22, began drilling near the mouth of the Hay River, south shore of Great Slave Lake, and got for its pains a flow of salt water at the rate of 360 gal. per minute. The well was abandoned.

In charge of the Fort Norman project for Imperial Oil at the outset was Charles E. Taylor, who died on a Mackenzie River steamboat in the fall of 1921. He was later succeeded by a frail-looking man of dynamic energy, Ronald MacKinnon, who has been

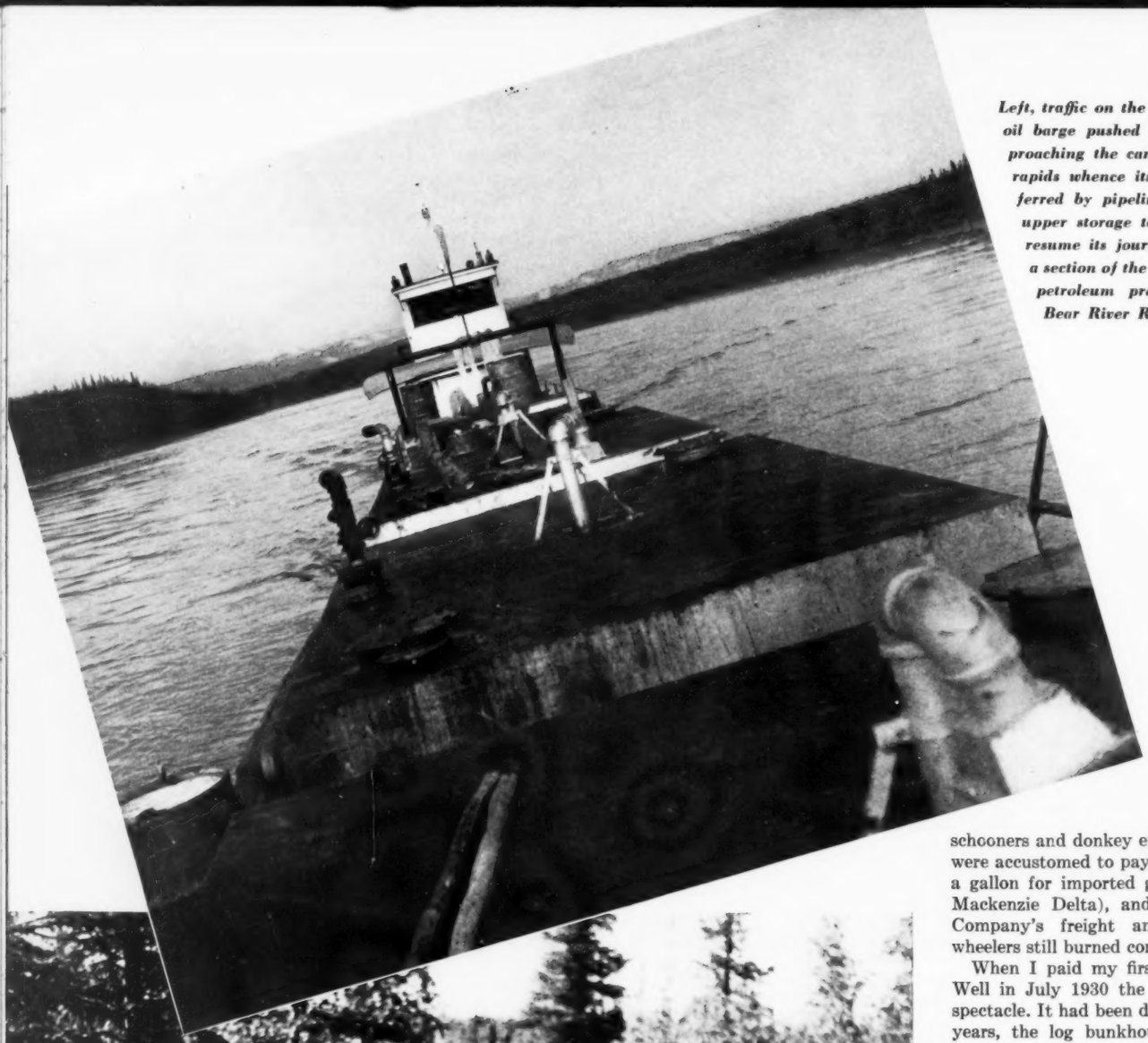
Above, the original rig used at Norman Wells to drill the discovery well in 1920. In 1939 it was still in use drilling No. 3 to a depth of 1,837 ft. Right, discovery well camp seen from the Mackenzie River. This picture was taken in 1939 after the camp had been rebuilt and its name changed to Norman Wells.

The Great Bear River Rapids which constituted a serious obstacle to shipment of equipment and transfer of petroleum products. The storage tank is the same as the one shown at the top of the opposite page.

the brains and guiding spirit of Norman Wells ever since.

The Norman strike directed public attention to the potentialities of the Northwest Territories and prompted the creation of a federal government branch to administer the natural resources of the region, including, of course, mining. The Director was the author's father, O. S. Finnie (now retired), who made his first inspection trip down the Mackenzie in 1921.

Premature was the excitement attending the Norman strike of Imperial Oil Limited, whose work in the Mackenzie District was just one phase of a long-range program of exploration across Canada. It was said that a pipeline to carry the oil 1,200 miles to railhead at Waterways would cost $40,000,000, which was out of the question. The local market included only a few motor boats, gasoline



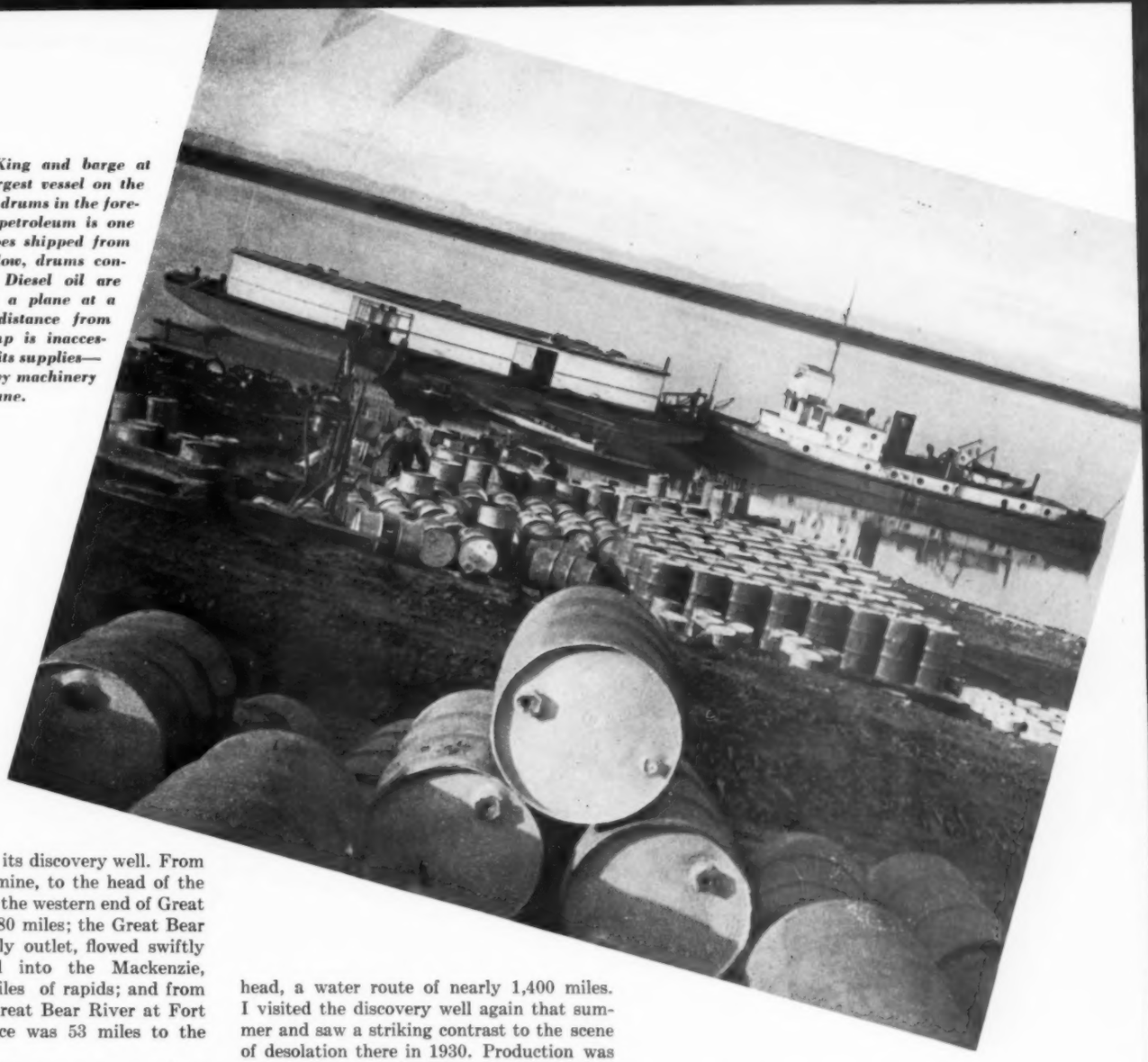
Left, traffic on the Great Bear River; an oil barge pushed by a power boat approaching the camp at the foot of the rapids whence its cargo will be transferred by pipeline eight miles to the upper storage tank and it will again resume its journey by water. Below, a section of the pipeline that portages petroleum products up the Great Bear River Rapids.

schooners and donkey engines, whose owners were accustomed to paying as much as $3.00 a gallon for imported gasoline (at Aklavik, Mackenzie Delta), and the Hudson's Bay Company's freight and passenger stern-wheelers still burned cordwood.

When I paid my first visit to Discovery Well in July 1930 the camp was a forlorn spectacle. It had been deserted for about five years, the log bunkhouses, workshops and drilling rig were languishing in desuetude, and grass and weeds were growing everywhere in almost tropical profusion. From the spout of the well casing oil dripped steadily, as if in protest against its neglect, and nearby little pools of seepage glistened in the warm sunlight.

For two years, airplanes belonging to or chartered by mining companies and syndicates had been combing the barren lands, and in the summer of 1930 the Royal Canadian Air Force began systematically photographing key areas of the Mackenzie District so that aerial mosaics could be assembled to facilitate the work of the prospector. Government geologists, too, were in the field. Promising indications of various base metals were found, and over on the east side of vast (12,000 square miles) Great Bear Lake, Prospector Gilbert LaBine staked claims on which he had seen veins rich in silver. The next season he was there again, and this time he made sure of a hunch he had had before: that his claims were laden with fabulously rich pitchblende. He had a mine, just about 37 miles south of the Arctic Circle, that was fated to break the Belgian Congo radium monopoly.

Now at last Imperial Oil had ample justifi-



Right, the Radium King and barge at Norman Wells, the largest vessel on the river at this point. The drums in the foreground indicate that petroleum is one of the principal cargoes shipped from this remote port. Below, drums containing gasoline and Diesel oil are being unloaded from a plane at a mining camp some distance from Yellowknife. The camp is inaccessible by boat, so all of its supplies—from dynamite to heavy machinery—are delivered by plane.

cation for reopening its discovery well. From Eldorado, the new mine, to the head of the Great Bear River at the western end of Great Bear Lake, it was 180 miles; the Great Bear River, the lake's only outlet, flowed swiftly 75 miles westward into the Mackenzie, bisected by eight miles of rapids; and from the mouth of the Great Bear River at Fort Norman the distance was 53 miles to the discovery well.

At once the problem was presented of getting the mine's pitchblende concentrates to railhead, and oil and gasoline from the discovery well to the mine. The Bear River had never been navigated except by canoes, York boats and small scows which were laboriously tracked up stream. Existing craft on the Mackenzie were wholly inadequate to meet the new need.

Meanwhile, in 1932, the discovery well was called into service again and a small steam still which had been set up in 1921 was operated to supply motor gasoline and Diesel oil for an expanding market: by this time there were many motor boats and kicker-propelled canoes running on the Mackenzie. The price of imported gasoline had been around $2.00 at the settlement of Fort Norman, but now the local product became available at 90 cents per Imperial gallon.

In the spring of 1934 there was a shipbuilding boom at Fort Smith, where a hundred men toiled to complete a flotilla of specially-designed freight barges and power boats in time for that season's navigation. A relay system was planned to transport heavy mining machinery, miscellaneous supplies, fuel and pitchblende concentrates to and from Great Bear Lake, Norman Wells and railhead, a water route of nearly 1,400 miles. I visited the discovery well again that summer and saw a striking contrast to the scene of desolation there in 1930. Production was going on apace, and gasoline could be bought at the well for 64 cents per Imperial gallon, fuel oil for 32 cents.

The pioneering project of getting 90-ft. long 50-ton barges with their loads up the swift, shallow Bear River, through the rapids and on to Great Bear Lake was costly and back-breaking, but it was done. The links of a remarkable transportation chain were forged that summer. I was there and took part in it, working on winches that dragged the boats by shore-anchored cables up stream a foot at a time, helping to pump out boats stove in by sharp boulders, and I rejoiced in the ultimate triumph of the barges and power boats as they reached the radium mine at Echo Bay.

In the summer of 1939 I returned to the Mackenzie District. Great changes and developments had been made since 1934. A town had sprung up on the North Arm of Great Slave Lake, a town with a population which at one time was estimated at a thousand men and women. Gold had been discovered, and now there were three mines actually in production—pouring more than $150,000 worth of gold every month in the year. Other mines were in the offing. Oil and gasoline were required here, and the cost of importing them from Alberta was exorbitant. Norman was filling the breach now, more than ever, drawing from two or three wells and sending 300,000 gal. of gasoline and fuel oil to Eldorado and twice that quantity to Yellowknife in a single season.

I paid my third visit in nine years to Norman Wells. Gasoline could now be bought here for 30-odd cents a gallon, and fuel oil for about 13 cents. Tractors rumbled to and fro, hundreds of steel barrels awaited shipment on the beach, big storage tanks gleamed in

the sub-arctic sunshine, while the original rig of the discovery well was drilling a new hole. A steel power boat with a freight barge attached bellied up to the shore. On the barge, about to be unloaded, was an 11-ton cracking tower that represented another milestone in the progress of the world's first far-northern refinery.*

Norman was supplying not only Eldorado and Yellowknife but also nearly a dozen settlements along the Mackenzie, and also, of course, all the Diesel-engined river boats. Among the customers were thrifty, sophisticated Eskimos who sailed their own barges from Aklavik to the wells, where—avoiding middlemen—they purchased wholesale lots of fuel for their motor schooners.

Hitherto only low-test gasoline and fuel oil could be produced at Norman Wells. The new equipment manufactured by Foster Wheeler and now being delivered meant that henceforth there would also be Intava Ethyl 87 octane aviation fuel, light Diesel oil, and probably a Bunker "C" heating oil.

The main fractionating column was made in one piece, 35 ft. long, with trays and caps bolted into place before shipment to save labor in the North. Fabrication of the stabilizer column was from standard 20-in. pipe sections. The heater was assembled at Foster Wheeler's St. Catherines, Ontario, shop with tubes in place and then shipped in two sections. Special lightweight insulating brick was sent in strong wooden cases. To reduce shipping weights, operators' platforms for attaching to the side of the tower were made of open grating instead of checker-plate. Because the water for condensing and cooling was to be taken from the muddy Mackenzie, the shell-and-tube units were designed for high velocity of the water to minimize fouling, with relatively high allowable temperature rise to keep the water requirements as low as possible.

The frost line at the Wells is about 50 ft. below the surface, dating back to the Glacial age. Each spring the soil is inclined to heave wherever there is any moisture and becomes spongy. In preparing the site for the new equipment, workers met difficult conditions in removing eight to twelve inches of moss and letting the ground thaw out.

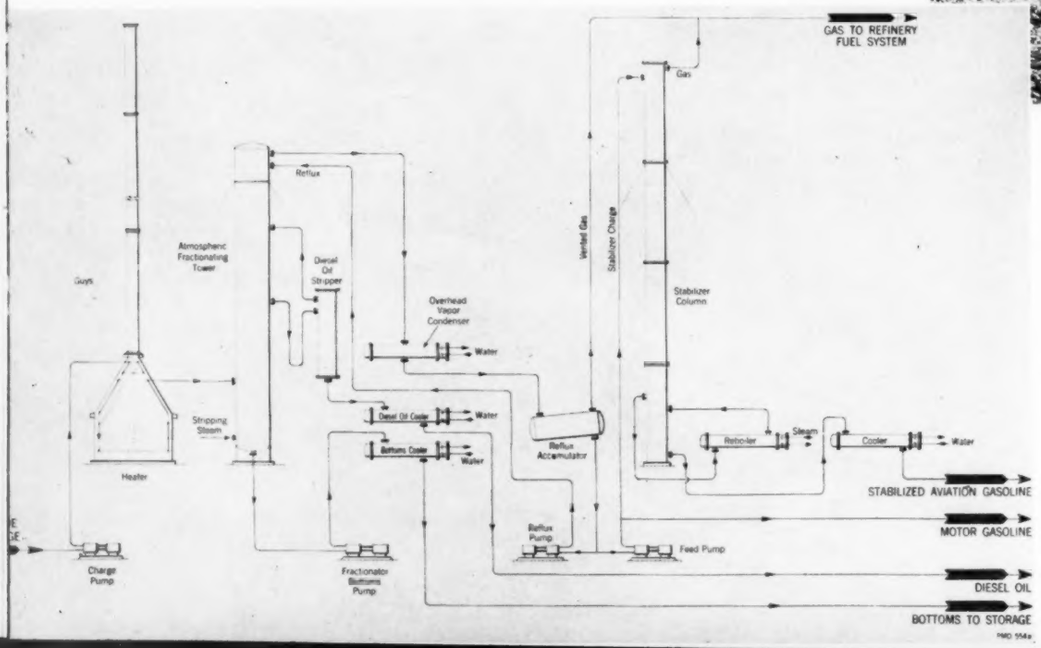
Grading was done in a quagmire. A tractor had to be kept on firm ground, dragging a slip scraper with a long line and tackle. To support the heater, fractionating tower and stabilizer, grillages of steel members were constructed to be used mat-fashion under each one to prevent tipping. Further support was furnished by guying the two towers and the 35-ft. stack. Foundations were dug down through the fill into the frozen ground and packed with gravel and river boulders.

The heater was bolted together after swinging the two shop-assembled sections into place and the whole was made rigid by cross-bracing. Instead of firebrick for the floor of the heater, local clay 18 in. deep was used—unique among oil heaters in this respect. To save other materials and yet obtain sufficient elevation the small vessels and piping were supported with driftwood timbers and welded sections of 4-in. and 2-in. pipe. A house was erected over the various pumps.

The refinery is designed for three alternate operations, producing a stabilized gasoline at 270 deg. F. Engler F. B. P., side-cut of light Diesel fuel oil, and heavy fuel oil bottoms for stationary Diesels with approximate yields, respectively, of 19 percent, 41 percent, and 29 percent. The side-cut can be eliminated, running all of the fuel oil as bottoms. It is also possible to run a 400 deg. F end point

*There are untapped oil deposits about 300 miles north of the Arctic Circle in Alaska, where the U. S. Government has set aside a reserve. Stefansson reported oil in association with coal in Canada's Melville Island, more than 600 miles north of the circle. In the Russian sector of the Arctic, the Soviets say that they have oil-bearing strata across the entire Taimyr region and in the Pechora basin. In 1936, according to the Moscow "*News*" of May 29, 1939, "the first oil derricks were erected on the Malaya Kheta River which falls into the Yenisei." It cannot now be determined whether the Norman Wells refinery is still the most northerly in the world, but it is generally regarded as such. (A Soviet atlas mentions an "all-chemical refinery" at Kirovsk, 67 deg. N., 33 deg. E.)

Above, plane taking on fuel at Fort Simpson on the Mackenzie River, the furthest north reached in the first (1921) flight into the Northwest Territories. Picture was taken at 11:00 o'clock at night in summer when there is no darkness in the arctic. Right, tractor drawing the fractionating tower up the hill to the refinery location. Below, simplified flow diagram of the Foster Wheeler refinery installed at Norman Wells. Opposite, the tower being landed and above, Eskimos watch a plane land at Aklavik, near the Arctic Ocean.



motor gasoline overhead and take Diesel fuel oil as bottoms.

The crude charge is introduced directly into the convection section in the upper part of the heater, without the use of any heat exchange equipment, and is brought up to temperature by firing a combination oil and gas burner. Omission of exchangers to preheat the charge is unusual but an economic study indicated that they could not be justified, due in a large part to the high freight charges. The heated oil flows to the fractionating tower where it is flashed at a point near the bottom. Live steam is used for stripping. Overhead vapors are condensed in a water-cooled condenser and collected in a combination reflux-accumulator and water separator. Any remaining vapors are vented from this drum into the refinery fuel system. Part of the condensate is returned to the top of the tower

as reflux to control the temperature at the top of the tower.

The net overhead may be pumped direct to storage if 400 deg. F. E. P. motor gasoline is the desired product. Normally, however, the net overhead is pumped to the top of the stabilizer column. This column is of the charge reflux type in which the feed flows down from the upper part of the column. Although this stabilizer has slightly higher losses than the usual type, it was selected in this instance for its simplicity. The heat required for stripping in the stabilizer is obtained from a steam-heated reboiler. Gas is vented from the top of the column to the refinery fuel system. Bottoms consisting of stabilized aviation gasoline are cooled and delivered to storage.

If a light Diesel fuel side cut is to be run, the stream is conducted to an external stripper operated with live steam. Vapors from the stripper are vented to the tower and the stripped Diesel fuel flows through a cooler to storage. Bottoms from the fractionating column are cooled and pumped to storage for use as required.

Only 30 days elapsed between the time the equipment for the refinery arrived at Norman Wells and the time the new refinery was put on a test run. Foster Wheeler engineers point out that although this new plant represents no great advance in the art of refining, it does indicate the value of the experience gained from far more complicated arrangements to produce a simple and conservative unit design to meet the peculiar problems of Arctic refining. All interconnecting piping was to be uncoupled each fall to prevent frost damage. It would be realigned in the spring of 1940, but extensive realignment would not be anticipated in following years because the foundations would probably not thaw out during any summer. All instruments were likewise to be disconnected and stored for the winter. Everything had to be simple and fool proof, of direct-acting mechanical type, since no service facilities were available closer than Calgary, Alberta.

Water pumps were not permanently set and must be shifted as necessary to meet the six-foot difference between high and low level in the Mackenzie River. When the ice goes out in the spring, the water builds up to 30 to 40 ft. above normal level, and debris in places is spread 250 ft. inland. All docks, gasoline and oil delivery lines for river boats, also water lines from and steam lines to the pump house, have to be dismantled and hauled up on top of the river bank proper before the crew leaves for the Outside. Upon the crew's return to the Wells around June 1st, all of this equipment must be replaced.

The Foster Wheeler combined distillation and stabilizer units as installed at Norman Wells are capable of refining the native crude at the rate of 840 bbl. a day.

From the Wells I started toward Great Bear Lake on a sternwheel boat and barge combination carrying 9,340 gals. of oil in bulk and gasoline in drums. (In 1934 I had watched this same sternwheeler, which was built at railhead and weighed 11 tons, being hauled out of the Slave River at Fitzgerald, trucked over the 16-mile portage and launched at Fort Smith.) Pushing her barge, the sternwheeler chugged up the Mackenzie to Fort Norman, then continued about 30 miles up the Bear River to a camp at the foot of the rapids. Here a hose was immediately con-

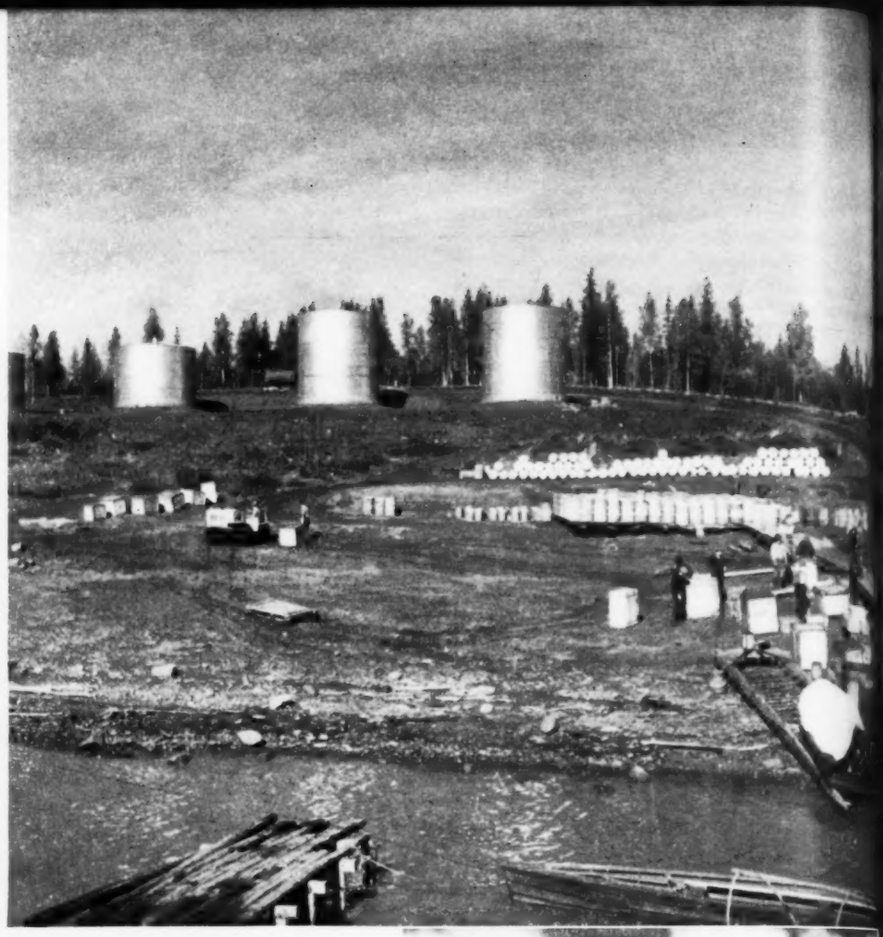
nected to the barge, and the oil was pumped up a hillside to an 18,000-gal. delivery tank. Thence it was forced through a pipeline eight miles in length, skirting the rapids, to a similar tank and fed as needed into barges running to the head of the Bear River. There, on the edge of Great Bear Lake, stood a 79,000-gal. tank which held the oil pending its transfer in other barges to Eldorado.

Meanwhile, some 30 tons of sacked concentrates together with empty steels from Eldorado, all of which had been brought by truck over a Government portage road (most northerly in Canada) from above the rapids, were piled aboard the sternwheeler and her barge for their return trip to Norman Wells.

Thus was the Bear River relay system operated; trip after trip, up and down all summer long, unceasingly, in which two boats and barges regularly ran below the rapids, another combination above the rapids, and two more shuttling back and forth across Great Bear Lake. Of varying capacities but uniformly shallow draft—the Bear River channel being only a couple of feet deep in places—all of these boats were Diesel-powered and, with the exception of the sternwheeler, had twin engines and twin screws.

They belonged to the Northern Transportation Company, an Eldorado subsidiary under the able general management of A. M. (Matt) Berry, veteran Arctic aviator, with Raoul Bertrand, Toronto mining man, personally directing the Bear River activities. During the season of 1939 they delivered 325,000 gal. of oil and gasoline to Eldorado, brought back 1,200 tons of concentrates and moved more than 500 tons of mixed freight. All of this was done in approximately 90 days, the period of operation for Norman Wells. The northern rivers are usually open between the end of May and early in October, but ice in Great Slave Lake may obstruct boat traffic on the Mackenzie until some time in June, while Great Bear Lake is navigable only from around the middle of July until the end of September, after which storms and imminent freeze-up make it dangerous.

Among the vessels used on Great Bear Lake was a steel tank barge 130 ft. long with a 35-ft. beam, its carrying capacity 69,000 gal. Its maiden voyage from Fort Smith exemplified some of the hazards entailed in this unique relay system. All went well until the massive barge was being warped up through the Bear River rapids late in the season. In



Above, a section of the waterfront at Norman Wells. The two tanks at the right hold 1,500 barrels of oil apiece. Right, Ronald MacKinnon, manager of Norman Wells. Below, forty-five-gallon drums of gasoline being rolled on to the Radium King at Norman Wells.

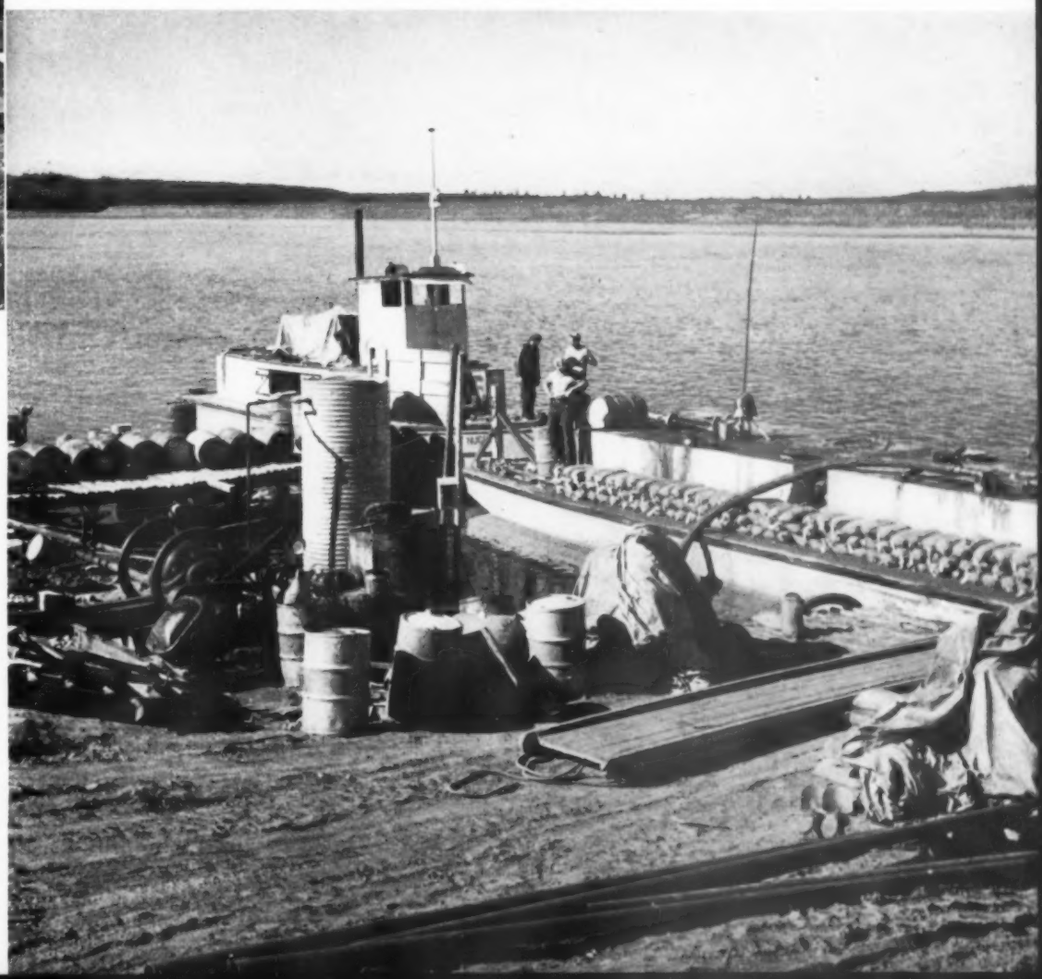
Above, a family of Dogrib Indians about to leave for a remote trapping camp; like all Mackenzie river Indians this family is a steady user of gasoline in their outboard motor. Left, Eldorado camp. Below, barge unloading just below the Great Bear River Rapids.

the midst of the torrent it swung against a rock and was punctured. Facilities then available were inadequate to move it, so it was left where it lay, willy-nilly, all winter. The following summer it was beached, repaired, and finally placed on Great Bear Lake. Every boat and barge on the lake or on the Bear River had taken a beating at one time or another. But mishaps were part of the job and they never kept the oil, gasoline and mixed freight from being delivered.

The Northern Transportation Company also had two steel tugs, the RADIUM KING and the RADIUM QUEEN, which carried oil, gasoline, mixed freight and passengers between Fort Smith, Yellowknife, Norman Wells and Aklavik. These were actually built at Sorel, Quebec, and moved in sections by rail across the continent to Waterways. Barges conveyed the sections to Fitzgerald, tractors pulled them to Fort Smith, and there they were reassembled and duly launched. It was the RADIUM KING that brought the new fractionating tower from Fort Smith to Norman Wells in the summer of 1939.

The Eldorado mine has temporarily closed down, its directors announcing that a surplus of uranium concentrates in storage at Waterways will keep their Port Hope, Ontario, refining plant supplied indefinitely. (Ninety percent of Eldorado's products have been exported, and the war has eliminated certain markets.) In the Mackenzie District generally, further exploration and budding enterprises are being somewhat delayed, but the demand for gold is greater than ever and Yellowknife's mines are going full blast. As soon as all of Eldorado's concentrates have been transferred to railhead, the energies of the Northern Transportation Company will probably be focussed mainly on the Mackenzie River and Great Slave Lake for a time, while production continues at Norman Wells to supply northern communities, boats and aircraft as well as mines.

Whatever happens in Europe, Canada is likely to have a rapidly growing population which will surely surge northward. The Northwest Territories comprise more than a third of the Dominion's area and are incalculably rich in natural resources. Moreover, the climate is healthful and once the bugaboo of an ever frozen, inhospitable North has been dispelled, large numbers of people may want to go there to settle down and carve out careers for themselves.



H_2S REMOVAL

Trend Toward Chemicalization of Refining Industry Accelerated by Emergency Conditions Reflects Prominence on Shell's Phosphate Process for Removal of Hydrogen Sulfide in Preparation of Charge Stocks for High Octane Blending Fuels.

By Henry N. La Croix
Design Engineer
Foster Wheeler Corp.

WITH the recent rapid changes in prevailing modes of both aviation and automotive transportation, the importance of high-octane number gasoline has increased tremendously and this effect has been keenly felt in refineries throughout the world. A principal result is the trend toward chemicalization of the refining industry through great advances in petroleum technology, particularly in America. These take the form of poly plants, alkylation plants for production of commercial iso-octane and isomerization of normal to iso-butane for alkylation feed, solvent plants for lubricating oils and extraction plants for removal of hydrogen sulfide, mercaptans and acids. Such processes are largely dependent on chemical affinities and reactions, and successful operation requires mastery of equilibrium distributions, laws of chemical mass action and physical chemistry. They are to be distinguished from the once-standard processes limited for the most part to simple heating, cooling and condensing, and involving ordinary distillation, thermal cracking and combustion.

Although the modern processes were largely developed during the past decade, there is every likelihood that the next ten years will see an even greater technological advance inspired by prevailing economic requirements and by the reckless pressure on the part of certain nations to extend their influence at any cost, with resulting bitter competition. Economic supremacy will demand adequate supplies of high-octane gasoline for aviation and automotive service to provide the better efficiencies of high compression engines.

The preparation of high-octane gasolines is economically beyond the scope of simple pyrolytic cracking and requires the use of special processes such as polymerization or alkylation to utilize fully the available raw materials. Charge stocks for these units are usually light hydrocarbons, such as methane, ethane, propane and butane, and the unsaturated or iso-relatives of these. These materials, however, are normally contaminated with organic impurities such as nitrogen or sulfur-bearing compounds. The impurities reduce the effectiveness or life of the catalysts employed in the new processes and frequently bring about side reactions, whose products are deleterious to the desired final products. Many of the undesired impurities may be removed much more easily and effectively by treatment of the charge stock than by later treatment since the compounds in the charge are far less intricate.

One of the most obnoxious of the various impurities that occur in charge stocks is hydrogen sulfide which reduces the net yield or effectiveness of product, poisons the catalyst, and forms undesirable sulfur compounds which are difficult to remove later. Fortunately, the hydrogen sulfide (H_2S) is easily removed from the charge stock by a number of methods, of which one of the most economical is the phosphate process. One of the latest plants of this type to go into operation is illustrated in the accompanying photographs.

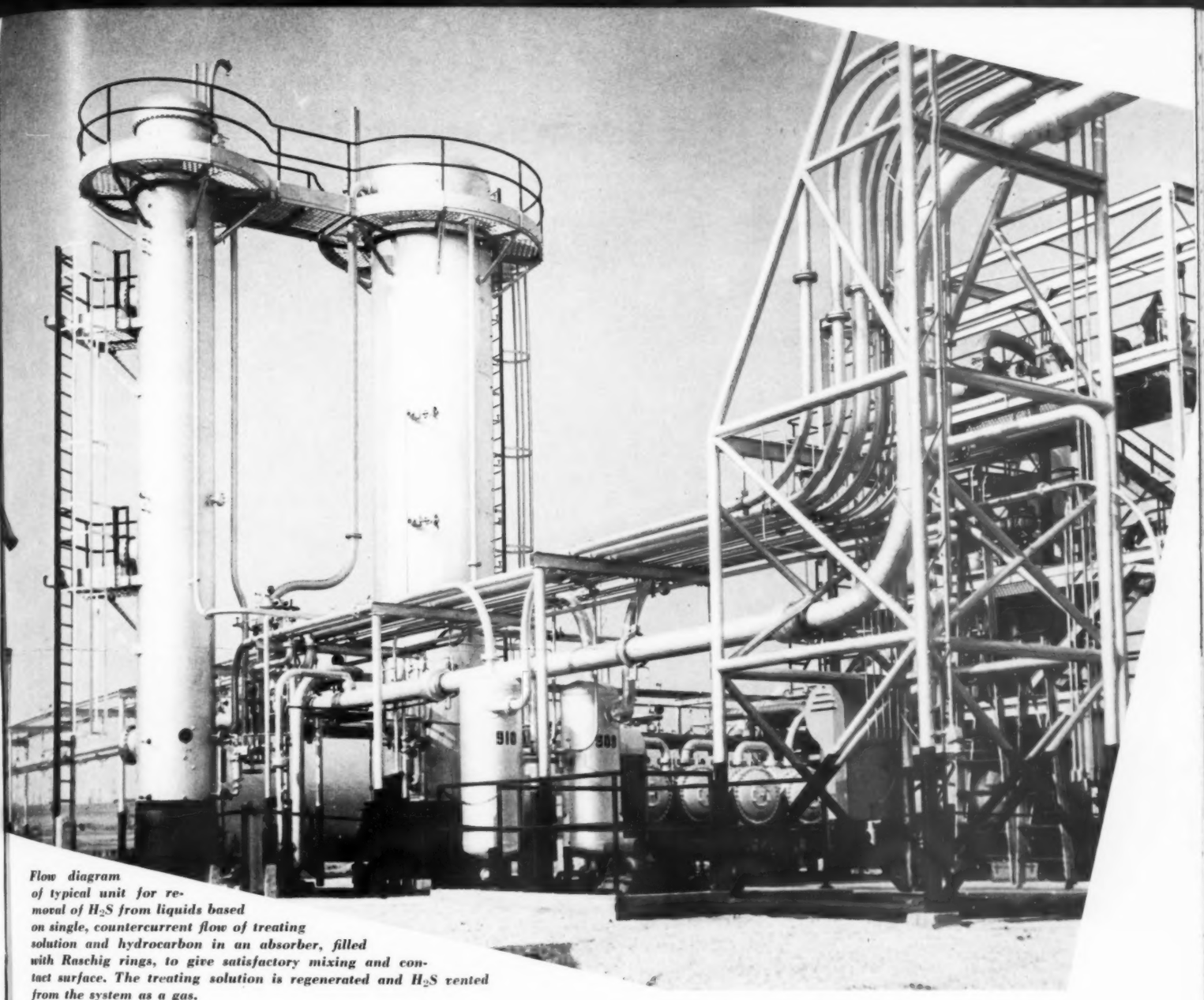
This is a liquid extraction unit preparing liquid hydrocarbons for charging to a catalytic polymerization plant. It employs the patented Shell Phosphate Process, using aqueous solutions of tri-potassium phosphate, which is applicable to removal of H_2S from both liquids and gases. In either system the hydrocarbon is contacted counter-currently with the phosphate solution in towers, and the absorbing solution is continuously regenerated and recirculated through the process.

The photographs clearly show the absorber tower, the simple regenerative equipment, and the mixing tank for preparing the phosphate solution, as well as the spine-tube heat exchangers which provide unusually high heat transfer rates. The phosphate salt may be prepared by chemical neutralization of the acid and alkali used, or it may be purchased in crystalline form, ready to be dissolved in water.

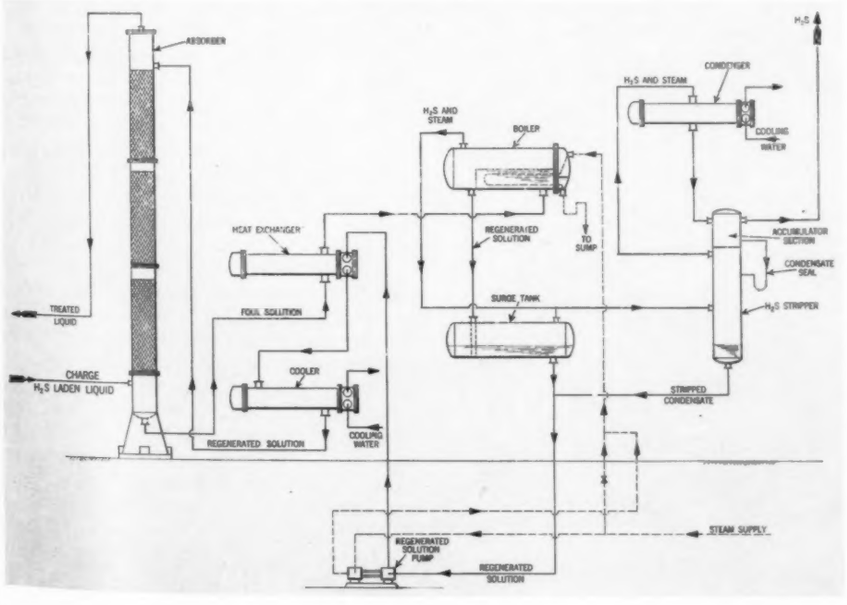
This plant was designed to operate on charge stock containing only 150 grains of H_2S per 100 standard cubic feet of gas, with provision for handling greater quantities if encountered. Due to the small quantity of H_2S to be removed, no condensate stripper

Opposite above, close up of two hydrogen sulfide absorption towers, cooler and heat exchangers.

Treating plant for removing H_2S from liquid charge stock to the catalytic polymerization plant at left. The absorber tower is in the center of the picture. In front of it are the boiler for regenerating the phosphate solution, heat exchanger bank, and regenerated solution mix tank. At the right are surge drums for the H_2S-laden charge and treated product.



Flow diagram of typical unit for removal of H_2S from liquids based on single, countercurrent flow of treating solution and hydrocarbon in an absorber, filled with Raschig rings, to give satisfactory mixing and contact surface. The treating solution is regenerated and H_2S vented from the system as a gas.

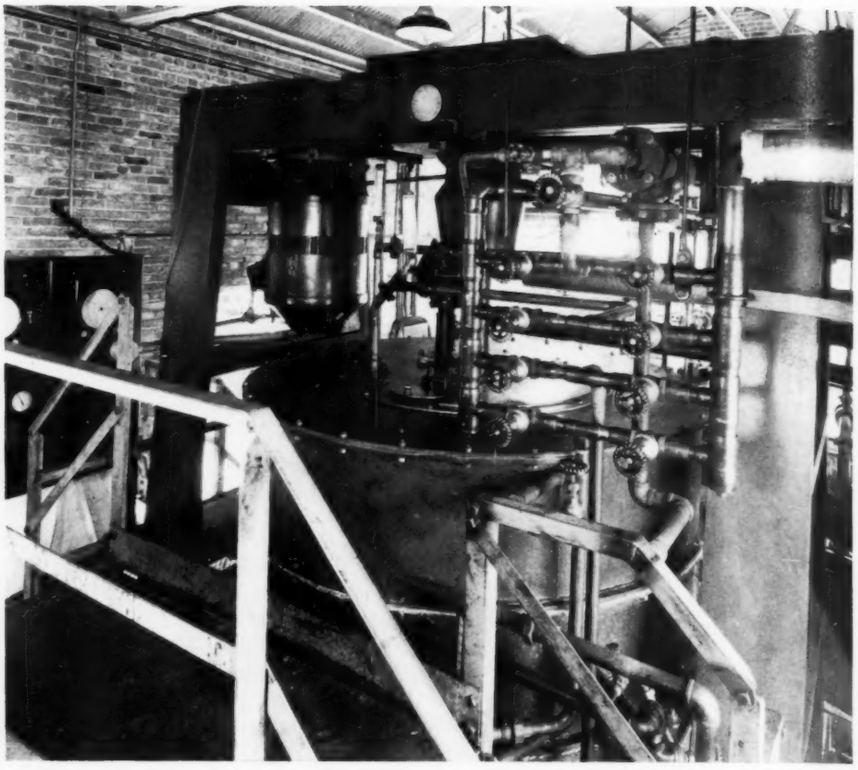


was needed. Operation to date has shown a reduction in H_2S content to as low as seven grains. The troublesome hydrogen sulfide is recovered in a gaseous state and is easily disposed of by burning in the boiler furnaces. Operation of the process is simple and costs for both initial installation and operation are relatively low.

A number of H_2S removal plants using the phosphate process are operating on charge stocks for producing various high-octane blending fuels as for example, polymerization units charging both gases and liquids, and alkylation units. The same purification process is also being used on natural gases, and by a manufacturer of iso-propyl alcohol. The phosphate process is attracting increasing attention of refiners as a simple and economical means of disposal of H_2S and is especially valuable in the preparation of high octane blending fuels.

Emulsion Process First New Wax Deoiling Method in Two Decades

Sweating Has Been Used For Many Years, Its Efficiency Occasionally Increased, But the Method Fundamentally Unchanged—A. H. Schutte of The Lummus Company in the Following Paper Being Delivered at the Annual Meeting of The American Petroleum Institute Describes an Entirely New Process for Deoiling Crystalline Waxes.



A 700 bbl. per day emulsion deoiling unit showing the 60 in. suspended centrifuge.

UNLIKE most refining processes, the separation of oil from crystalline waxes by conventional sweating has not been radically changed for the past two decades or more. The work of many investigators has increased the efficiency of sweating by extending our knowledge of the factors involved and by improving the control methods. The equipment has been improved by mechanical refinements, but the method of separation has remained the same. Sweating is still a batch fractional melting, carried out on long time-cycles, thermally inefficient and relatively difficult to control.

A new process has now been developed, based on a novel mechanism of wax-oil separation. While the application of this principle permits the separation of any clean oil-wax mixture, the commercial development of the process has thus far been confined to deoiling sweater stocks. This has progressed from a pilot plant operation on a wide variety of stocks, to commercial installations of 400 and 700 bbl. daily charging capacity. It offers the advantages of continuous operation under automatic control, low operating cost, and low plant cost.

TABLE I

Typical Data - Pilot Emulsion Deoiling Unit

Charge Stock Source	Charge Melting Point	Charge Percent Oil*	Product Wax Melting Point	Product Wax Percent Oil*	Yield Vol. per-cent on Charge	Number of Deoiling Steps
1. E. Texas Pressed Slack Wax	107	26	122.5	1.7	40.2	3
2. E. Texas Pressed Slack Wax	107	26	129.5	0.5	25.8	5
3. E. Texas Pressed Slack Wax	112.5	30	122.5	10.7	57.5	1
4. M. C. Cold Pressed Slack	96	(too high)	115.5	11.8	13.3	1
5. M. C. Cold Pressed Slack	96	(too high)	105	34	36.0	1
6. Penn. Solvent Dewaxing Slack	122.5	(10.0)	127	(0.7)	62.0	1
7. Penn. Solvent Dewaxing Slack	122.5	(10.0)	130	(0.2)	41.5	1
8. Penn. Slack Wax	113	(20)	122.5	(5.5)	72	1
9. M. C. Pressed Slack Wax	108	36.6	115	16	71	1
10. M. C. Pressed Slack Wax	108	35.6	119.5	5.5	43.8	1
11. M. C. Pressed Slack Wax	108	51.4	118	26.6	51.4	1
12. Far Eastern Wax Stock No. 1	99	32.6	107	13.6	34	1
13. Far Eastern Wax Stock No. 1	99	32.6	109	7.3	24.8	2
14. Far Eastern Wax Stock No. 2	116	11.8	118.5	7.1	86.5	1
15. Far Eastern Wax Stock No. 3	135.1	3.9	138.5	1.2	72.2	1
16. M. C. Pressed Slack Wax	108.5	36	117.6	16.5	64.1	1
17. E. Texas Pressed Slack Wax	105.6	42.2	115.8	20.3	60.2	1
18. California Solvent Dewaxing Slack	121.6	25.1	128.7	2.0	59.0	1

*Oil contents run by modified ASTM procedure using special light cloth, correlated with solvent method. Oil contents enclosed by parentheses run by ASTM method D-306-29T.

THEORY

If an oily crystalline wax stock is cooled to a temperature below its melting point the wax solidifies in well defined crystals, but the system is not freely separable because the wax crystals impede the flow of the oil, and because the oil adheres to the crystals. An attempt to filter the material results in very imperfect separations and difficulty with plugging of the filter medium. If, however, the oily wax is emulsified in a non-viscous non-solvent liquid, such as water, and cooled to precipitate the desired wax, with the process so controlled that the water is the continuous phase of the emulsion, then the droplets of oil and the wax crystals are separated by water, and a freely filtering substance is obtained. In practice the cooling and emulsification are usually carried out in the same zone by the addition of the non-solvent liquid at a suitable temperature. The resulting material, which has the appearance of whipped cream, may be subjected to any kind of a liquid solid separation, such as filtration or settling. The cake deposited on filtration, when the water and oil have been removed, is finely crystalline, porous, and may be readily washed with large volumes of

water. A further fractional separation may be obtained by varying the temperature of subsequent water washes. It has been found that one of the most efficient methods of separating these emulsions, is to charge them to a filtering-type basket centrifugal, suitably jacketed for temperature control and equipped with washing nozzles. When washes are used at temperatures considerably higher than the temperature of the charge emulsion, a partial shrinkage of the cake results in a squeezing action which aids the removal of the last traces of oil. When treated in this way, the cake still retains its porosity, however, and allows a free passage of the wash liquid.

It will be noted that the process has the unique features of employing non-solvent liquids, rather than solvent liquids, and of utilizing emulsions, which up to now have been considered as undesirable nuisances by the petroleum refiner. In addition to the above mentioned benefits of emulsification, there is apparently an improvement in crystal structure, due to the fact that the wax is solidified from a thin inter-facial film, rather than from the main body of a liquid. This effect has been noted in the commercial deoiling of waxes containing high end-point constituents, which would render them virtually unsweatable. In this case the film crystallization apparently decreases the effect of the naturally occurring inhibitors.

TABLE II

Pilot Plant Data - Single Stage Emulsion Deoiling Followed by Sweating

Emulsion Deoiling Operation—Once Through				
Charge	E. Texas Pressed Slack Wax			
M. P., deg. F.	112.5			
Percent Oil	29.8			
Cake				
Yield, Volume percent on Slack	57.5			
M. P., deg. F.	122.5			
Percent Oil	10.7			
Filtrate				
Yield, Volume Percent on Slack	42.5			
M. P., deg. F.	93			
Single Sweating Operation				
	Cut No. 1	Cut No. 2	Cut No. 3	Semi-Refined
Volume Percent on Deoiled Cake	20.6	2.1	38.3	39.0
Volume Percent on Original Slack	11.9	1.2	22.0	22.4
M. P., deg. F	95	115.5	123.8	132.0
Percent Oil	....	15.6	0.8	0.14
Tensile Strength, No./sq. in.	....	.....	.....	412

The equipment for single stage emulsion deoiling is shown on the flow sheet, Figure 1. The oily wax to be processed is introduced by pump G-1 into the suction of the emulsifier G-2. The volumetric capacity of the emulsifier is 10 to 20 times the quantity of wax charged, and this excess material is bypassed back to the emulsifier section. A small amount of compressed air is introduced with the wax. The temperature of the net emulsion is controlled by an automatic instrument operating on the water introduced to the emulsifier. The proportions of water and wax are adjusted by controlling the temperature of the water in exchanger E-1. The net emulsion is charged to a perforate-wall centrifugal lined with a filter medium. The unsolidified portion of the original waxy charge and the emulsified water are thrown out and collected in the lower portion of the jacketed housing surrounding the rotor. The deposited cake travels continuously up the wall of the machine as an annular mass and is discharged over the top lip of the basket into a steam-jacketed melting ring, from which it flows to one compartment of tank F-2. The cake may be washed during its progress up the wall of the machine at several levels by water at controlled temperatures. The upper wash material may be withdrawn and used as a recycle stock.

FIG. 1
EMULSION DEOILING PROCESS

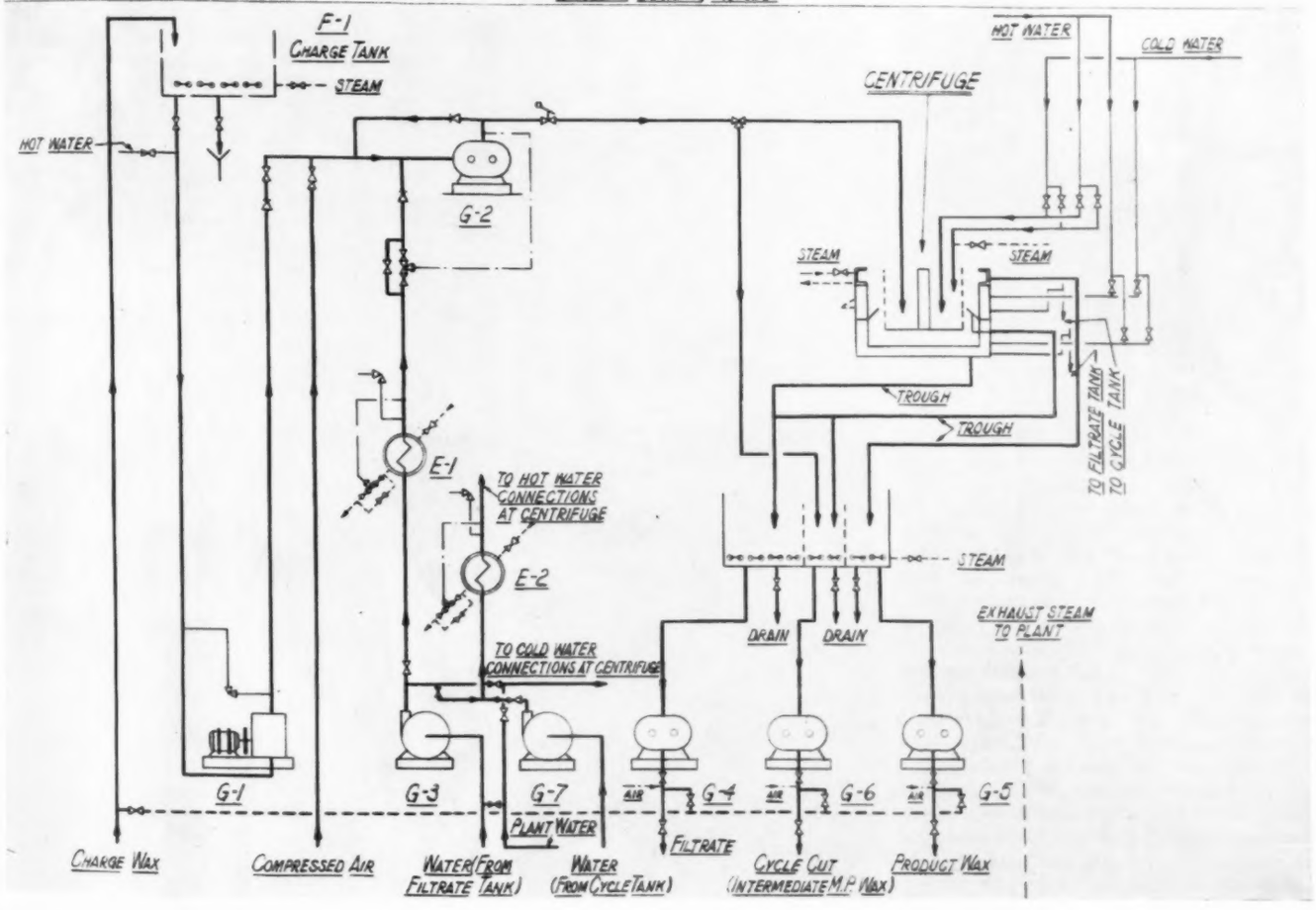
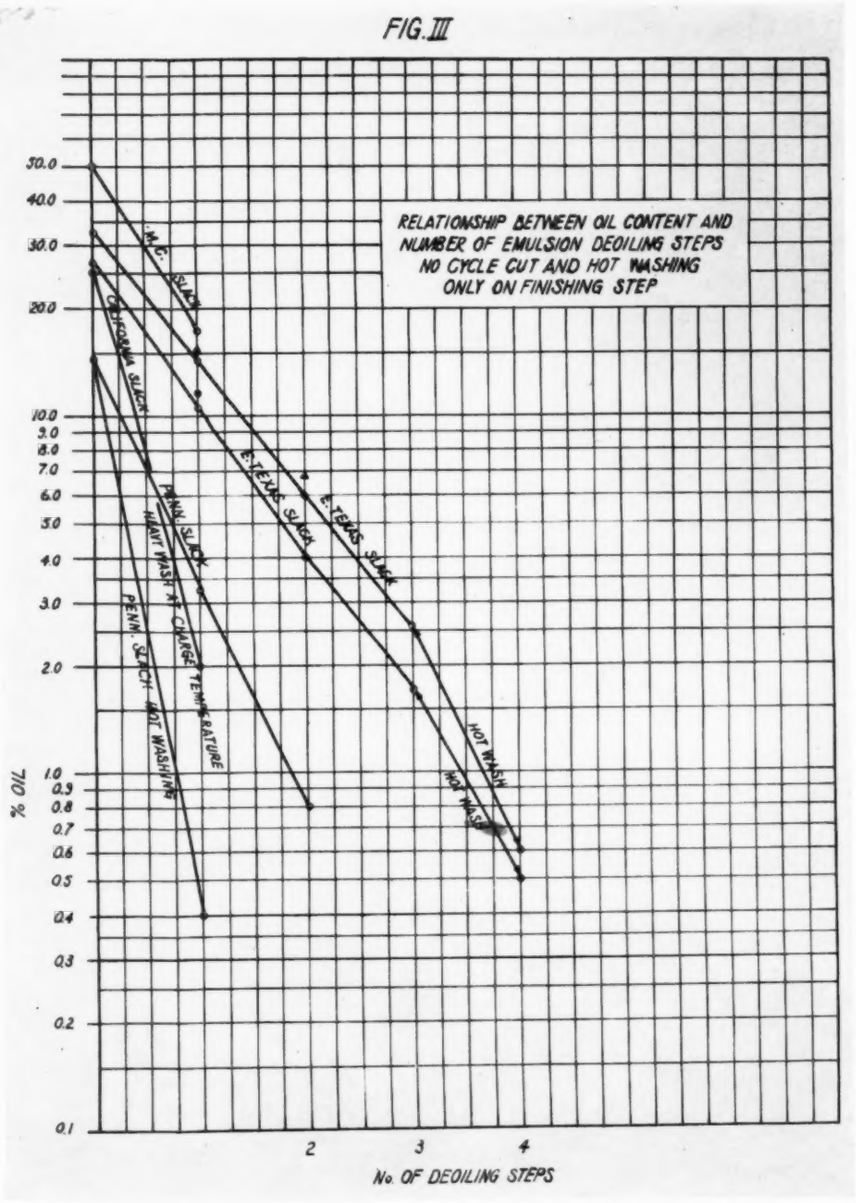


FIG. III



The operation of this type of centrifugal may be more clearly seen by reference to the cross sectional cut given in Figure 2. The machine differs from a conventional basket type filtering centrifugal in that the curb housing is divided into three jacketed sections. The top section is steam-heated for cake melting and the other two sections allow control of the temperatures in the primary filtration and washing zones. There is no mechanical means required to propel the cake upward and cause its continuous discharge, since the characteristics of the emulsion cause a self-propulsion of the cake. Due to the presence of emulsified water in the charge, the density of the material at the feed point is considerably greater than the density of the deposited cake. The internal pressure, acting on any particle of dry cake, is considerably less than that acting on a particle of feed slurry. This results in a net upward force in the cake which displaces it as an annular mass upwards along the wall of the rotor. Studies of this action have been made by introducing feed slurries containing insoluble dies. Cakes formed in this way were then cut into strips and removed. The line of demarcation between the undyed original cake and that deposited from the dye-containing subsequent charge is roughly a half-parabola having its axis along the surface of the filter medium.

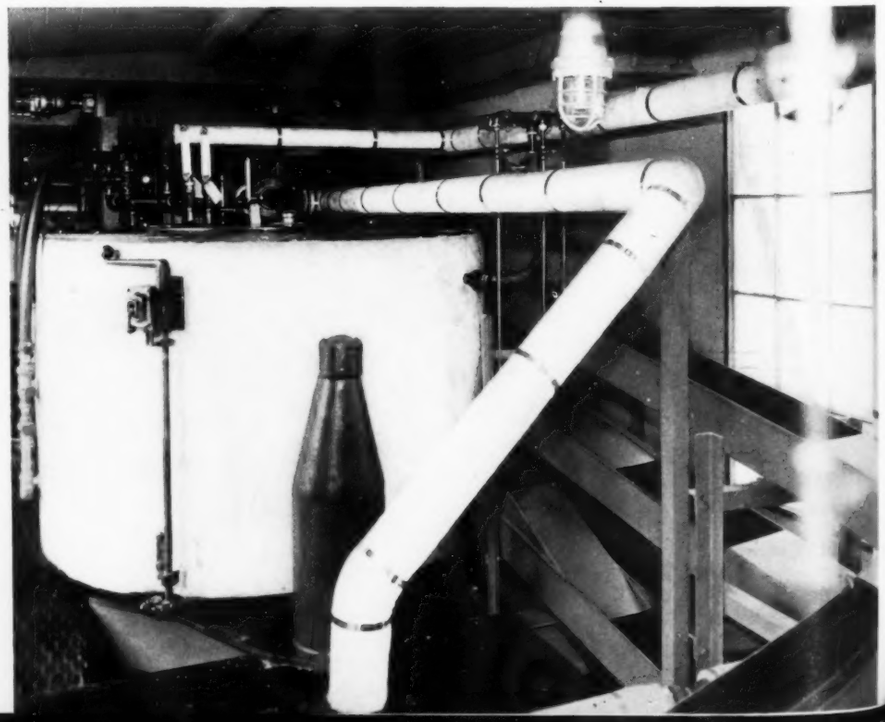
A view of the pilot deoiling unit is shown on page 87. This uses a 10-in. centrifugal which was remodeled from a standard small laboratory machine. The charging capacity of the unit is 10 gal. per hour.

The first commercial plant was built in an automobile box-car, and so designed that the car can be placed on a refinery siding, requiring only the connecting of electrical power and exhaust steam, water, charge, and product lines. This plant was designed for 400 bbl. per day of slack wax and has exceeded this capacity in service. Several views of this portable deoiling unit are shown in the accompanying illustrations. This plant has been operating since early in 1940 in Pennsylvania fields, producing marketable wax from slack wax obtained by solvent dewaxing. The refinery has no sweating equipment, and this box-car plant, plus clay percolation equipment, constitutes the entire wax plant.

One of the accompanying illustrations shows a 60-in. suspended centrifugal in a permanent 700 bbl. per day installation. The wash and jacket water control manifold and part of the instrument board may be seen. This unit operates on a Mid-Continent slack wax from plate and frame presses.

RESULTS

Typical data for pilot plant emulsion deoiling operations on various stocks are presented in Table I. These stocks include three East Texas pressed slack waxes, Mid-Continent cold pressed slack, Pennsylvania



A 48 in. centrifuge in an emulsion deoiling unit.

and California solvent dewaxing slacks, and Far Eastern wax stocks. In most of these runs hot washing was used only on the final finishing step, since the pilot unit has no side cut to segregate the hot wash filtrate from the primary filtrate or foots oil. The degree of oil separation obtained on the California solvent dewaxing slack in a single step process is much greater than that shown for the other stocks. This is a reflection of the improvements made in the pilot plant equipment in the last few months. Figure 3 is a plot which shows the relationship between the oil content of the charge wax and the oil content of the cake obtained from each deoiling step when hot washing is used on only the final operation. It will be noted that there is a definite and constant relationship between the oil contents remaining after each pass. With the exception of the California slack wax, this relationship indicates the equilibrium obtained in the original emulsion charged to the centrifugal. In the case of the California stock, several improvements have been made in the emulsification system and a heavy, well distributed wash was employed at the charge temperature. The factors influencing the degree of oil separation are as follows:

1. The crude source from which the slack wax is obtained. This effect will be noted by the difference in the slopes of the lines for well fractionated, sweatable, slack wax from various crude sources.
2. The percentage of oil in the original charge.
3. The degree of fractionation obtained in the distillation unit which produced the original wax distillate. As pointed out previously, this effect is less important in emulsion deoiling than in conventional sweating. Poorly fractionated slack wax usually gives no trouble with operation in emulsion deoiling, but the structure of the final product wax is apt to be poor. The curves of Figure III are given to show the relationship between the oil content of the charge and that of the solid phase in the original emulsion and they do not represent the ultimate separation possible by washing and by the segregation of the hot wash filtrate.

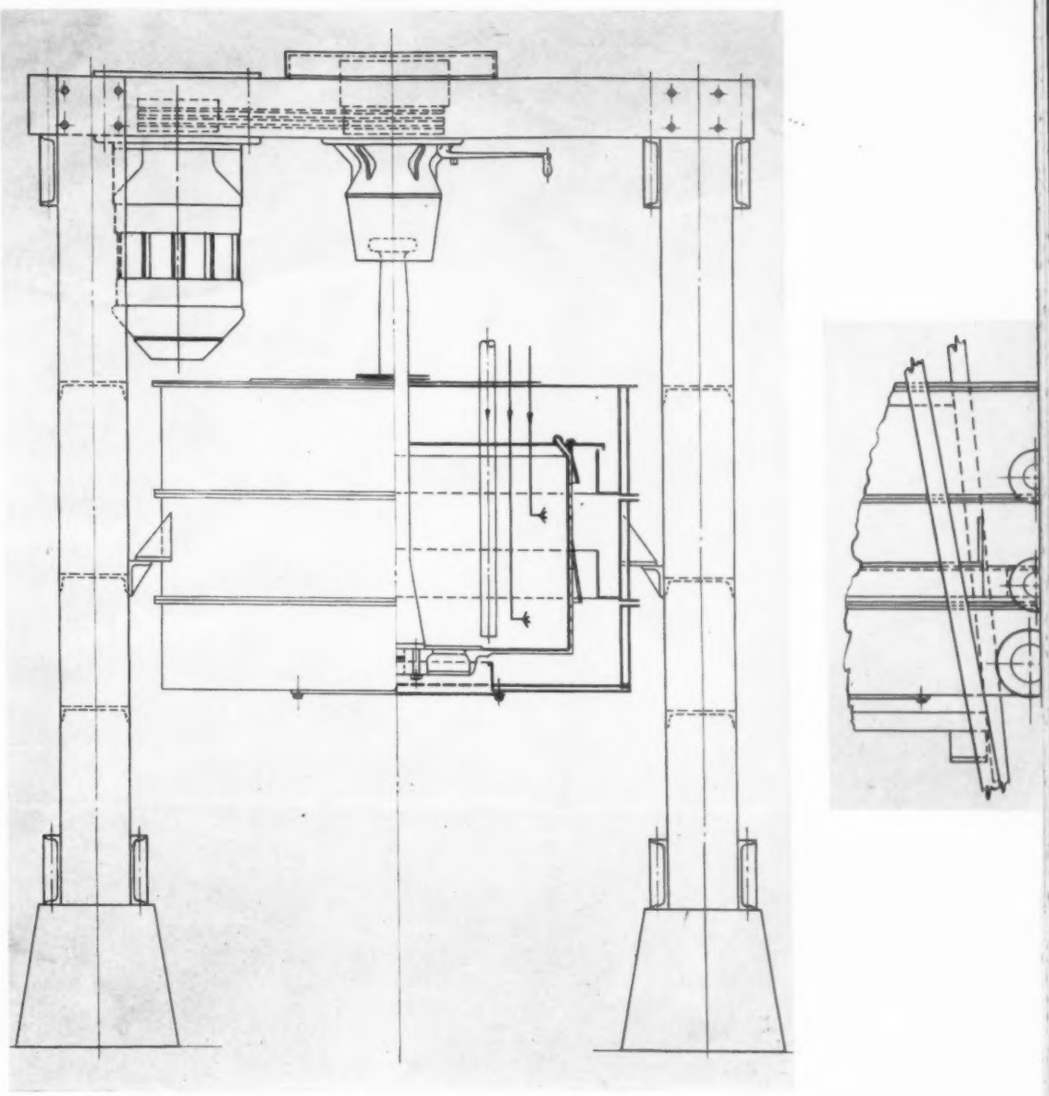


Figure 2: Cross-sectional drawing of the centrifuge used in emulsion deoiling operations.

TABLE III

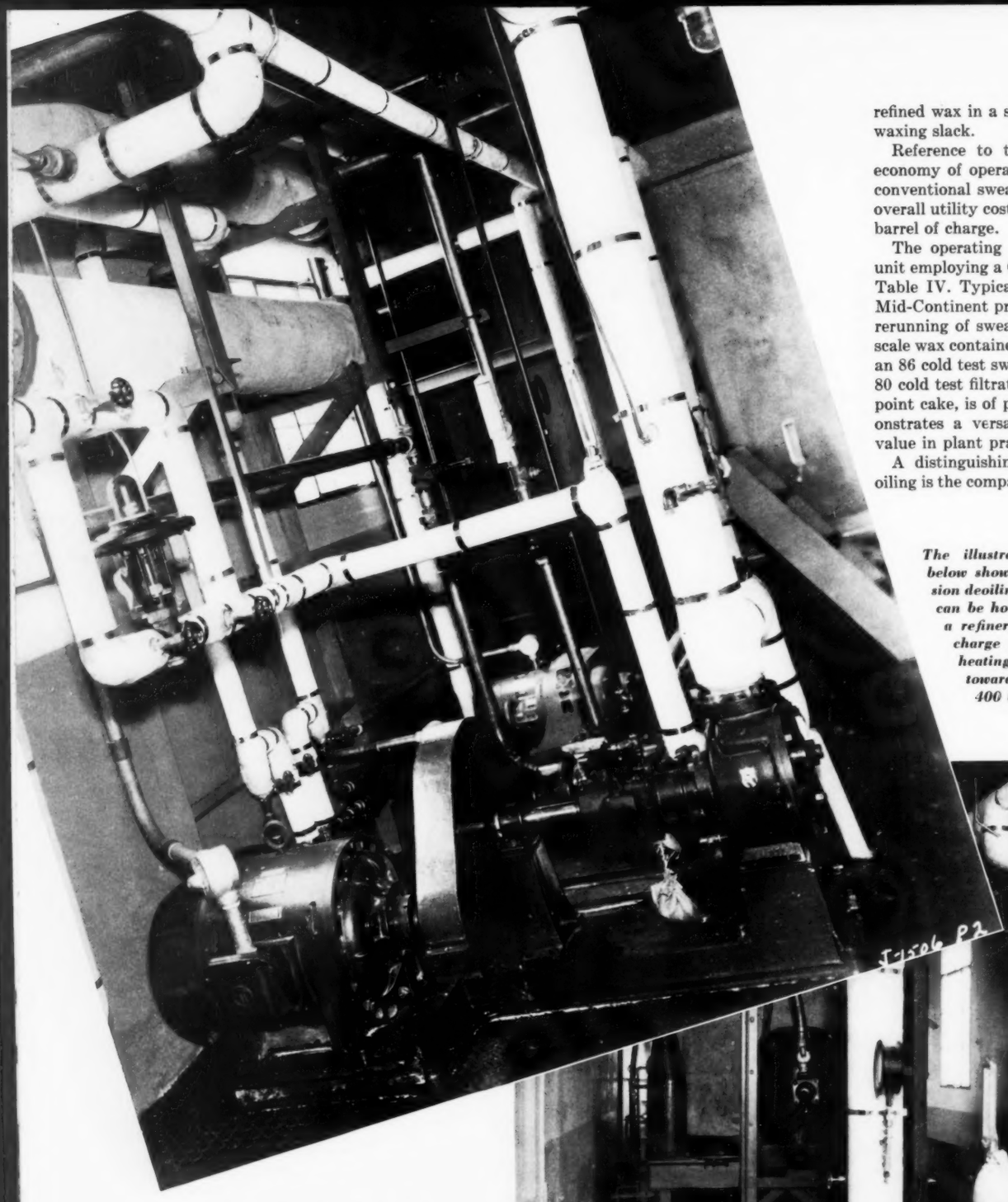
Plant Data—Emulsion Deoiling Operations—Commercial Operation 48″ Centrifugal

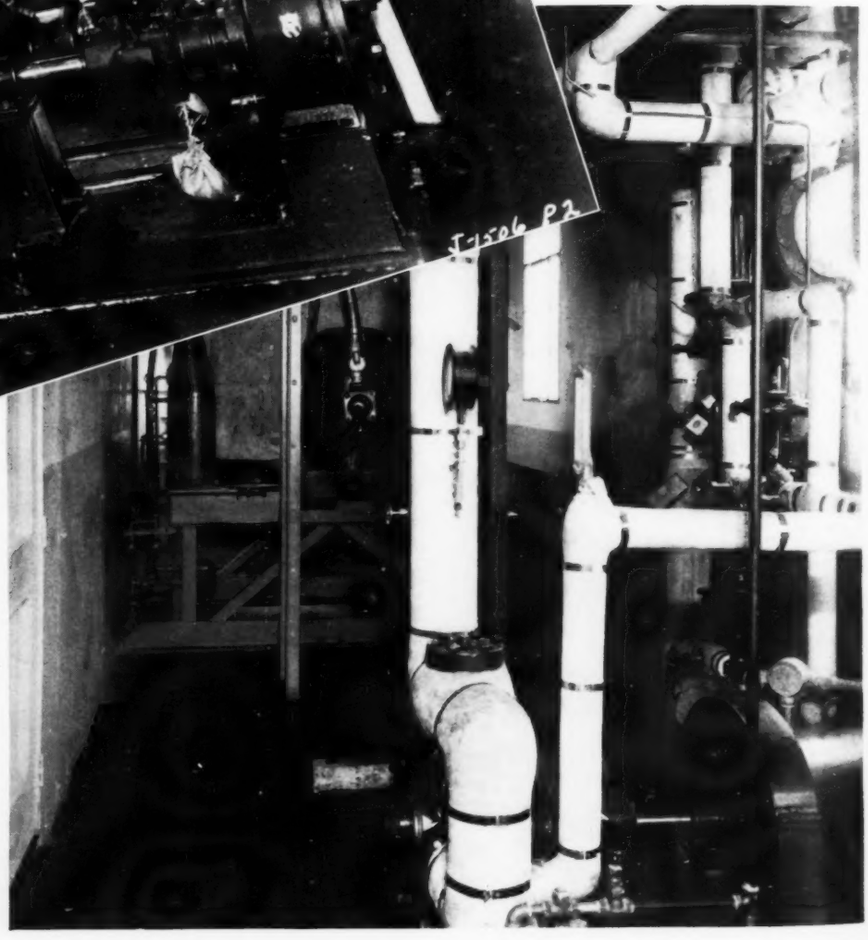
	A	B	C	D	E	F
	B-A Slack Wax from 125 Vis. Dist.	Cycle from A	B-A Slack Wax. from 50 percent 80 Vis.-50% 250 Vis. Dist.	Accumulated Filtrate from Other Operations	Coke from D	P-A Slack fro 155 Vis. Dist.
Charge Stock						
M. P., ASTM	125-127	124	118.6	114.4	123	120
Percent Oil, Press Method	4-11	5	14.3	21	1.3	6
E. P.—10 mm.	590-615	.....	680 to 700	.....	.....	.....
Cake						
Volume Percent on Charge	52	45.2	47.3	48	52	43
Volume Percent on Slack Wax	52	8.6	47.3	.....	.....	.....
M. P., ASTM	130-131	129.1	128.6	123	129	130
Percent Oil, Press Method	0.4-0.7	0.4	0.4	1.3	0	0
Filtrate						
Volume Percent on Charge	29	54.8	52.7	52	.....	.....
Volume Percent on Slack Wax	29	10.4	52.7	.....	.....	.....
M. P., ASTM	118	118.8	110	.....	.....	.....
Percent Oil, Press Method	.....	13.3	.....	106	.....	.....
Cycle						
Volume Percent on Charge	19	.....	.....	.....	.....	.....
Volume Percent on Slack Wax	19	.....	.....	.....	.....	.....
M. P., ASTM	124	.....	.....	.....	.....	.....
Percent Oil, Press Method (A and B)	5	.....	.....	.....	.....	.....
Overall Scale Wax, Volume Percent on Slack		60.6	.....	.....	.....	.....
Overall Filtrate, Volume Percent on Slack		39.4	.....	.....	.....	.....
Charge Rate, B/D	396	495	.....	430	430	400
No. hrs. Exh. Steam	660	(40/bbl.)				
G. P. M. Water, No Reuse	19	(69 gals./bbl.)				
K. W. H. Power	26.5	(1.62 KWR/bbl.)				
Utility Costs						
Cents/bbl., Slack, Steam ***	1.000					
Cents/Slack, Water	.035					
Cents/bbl., Slack, Power	.81					
	1.845					

***Steam at 25 cents/1000#, water at 0.5 cents/1000 gals., power at 0.5 cents/KWH.

Table II gives the result obtained by a single stage emulsion deoiling of an East Texas pressed slack wax, followed by a single laboratory sweating. The original slack charged to the emulsion deoiling operation had a melting point of 112.5 deg. F., and contained 29.8 percent oil. A yield of 57.5 percent of cake was obtained with 122.5 deg. F. melting point, and an oil content of 10.7 percent. This cake sweated to 22.4 percent on the original slack of 132 melting point semi-refined wax, having an oil content of 0.14 percent and over 400 tensile strength. The next cut of 22.0 percent on the slack was of 123.8 melting point, 0.8 percent oil. This shows that stocks which have been partially deoiled by the emulsion process give good separations upon subsequent sweating and yield products of high quality.

The results obtained from the commercial





refined wax in a single step from solvent dewaxing slack.

Reference to the utility data shows an economy of operation in marked contrast to conventional sweatings; as evidenced by the overall utility cost of only 1.8 to 1.9 cents per barrel of charge.

The operating performance for a deoiling unit employing a 60-in. centrifugal is given in Table IV. Typical operations are shown for Mid-Continent pressed slack wax and for the rerunning of sweater foots oil to recover the scale wax contained therein. The operation on an 86 cold test sweater foots oil producing an 80 cold test filtrate and a 113 deg. F.melting point cake, is of particular interest and demonstrates a versatility which should be of value in plant practice.

A distinguishing feature of emulsion deoiling is the compactness of the equipment, as

The illustration at left and the two below show the portable unit for emulsion deoiling installed in a box car which can be hooked up in a few hours near a refinery. At left may be seen the charge pump, emulsifier and water heating exchangers; below, looking toward the centrifuge. Unit handles 400 bbl. per day.

operation of an emulsion deoiling plant having a 48-inch centrifugal, are given in Table III. The charge stocks were obtained from solvent dewaxing of Pennsylvania distillates and the plant was usually operated for a high melting point crude scale product. It will be noted that the overall yield was 60.6 percent of 130 melting point scale wax, containing 0.4 percent oil. The operation shown in column "C" is of interest because of the high degree of separation obtained on a charge material containing high end point waxes which would normally be unsweatable. The oil separation from 21 percent to 1.3 percent upon rerunning the filtrate, is also of interest. The operation in column "F" show the production of a semi-

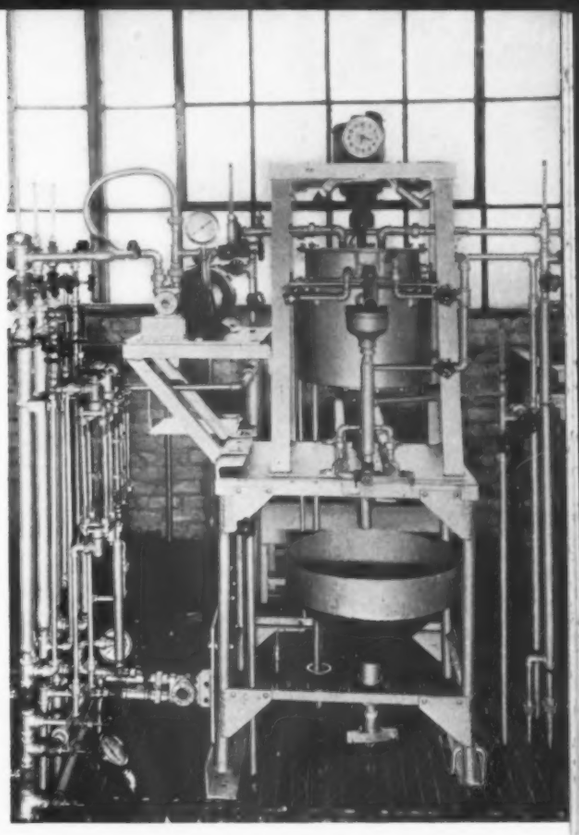
TABLE IV

Plant Data—Emulsion Deoiling Operations—60" Centrifugal

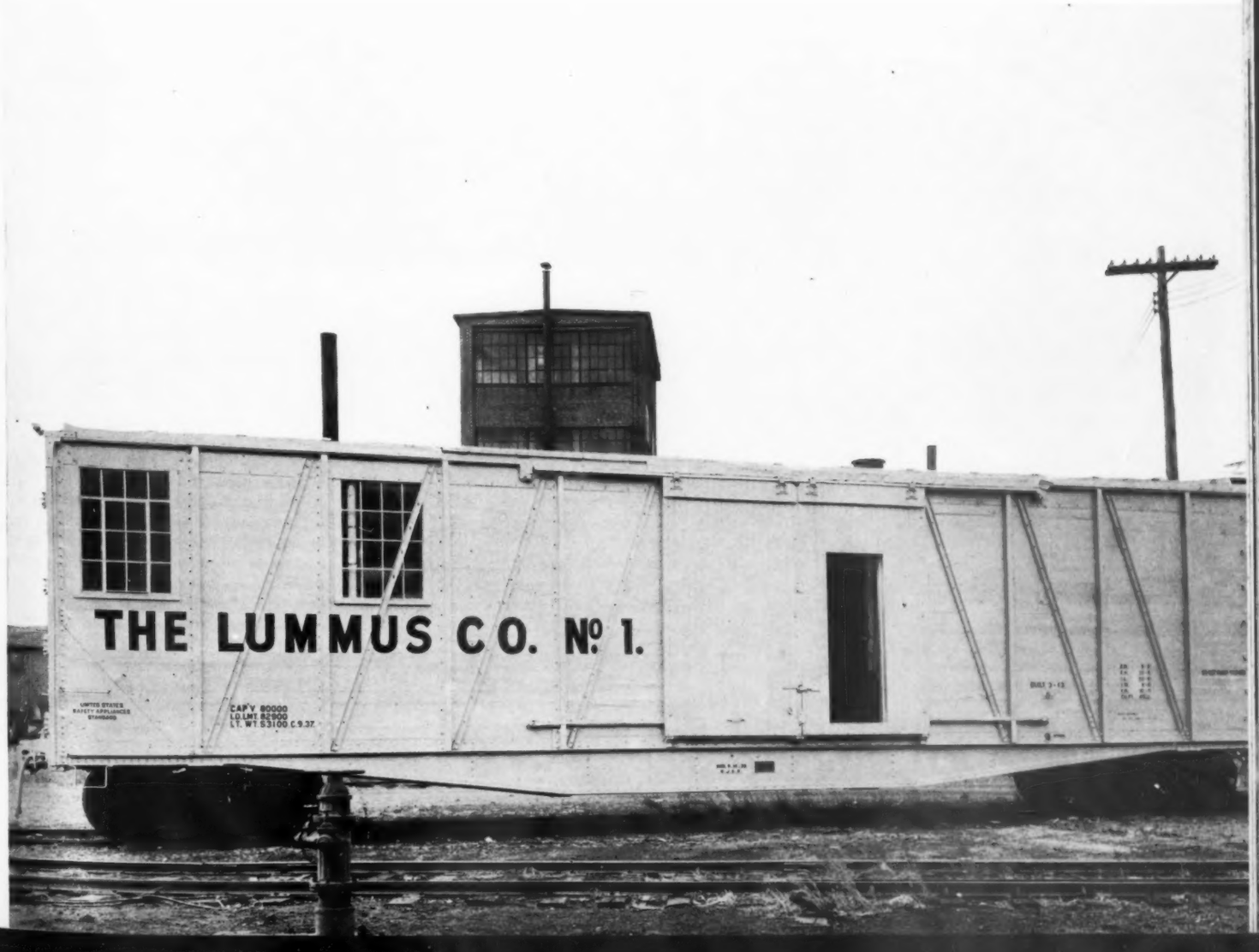
		Slack Wax from M.C. Crude		Sweater Foots Oil
Charge				
Throughput, B/D		620 (750 gross)		338
Volume Percent Cake on Charge		68.0		14
Charge Inspections				
M. P., deg. F., ASTM		106.8		86
Percent Oil, Press Method		45+		(cold test)
Cake Inspections				
M. P., deg. F. ASTM		116.5		113
Percent Oil, Press Method		16		26
Filtrate Inspections				
M. P., deg. F.		85		81
Cold Test, deg. F.		82		80
Cloud Test, deg. F.		85.8		81.5
Percent 122 M. P. Wax, Solvent Method		14.3		10.5
Direct Operating Cost Cents/bbl. charge				
Power	1.3 KW/bbl.	1.0	2.5 KW/bbl.	1.62
Water, 77 deg. F.	345 Gals./bbl.	0.17		Reused
Refrigeration		....	56.3 Tons*	1.69
Labor	1 Man/Shift	3.0	1 Man/Shift	7.10
	Total	4.17		10.41

*Based on reuse of water and net cooling by steam jet refrigeration.
Water @ 1/2 cents per 1,000 gals., 77 deg. F.
Power @ 1/2 cents per KW.

evidenced by the installation of a 400 bbl. per day unit in a box car. All process heat requirements are met by low pressure exhaust steam and therefore wax production capacity is obtained without additional boiler load. The equipment may be operated at emulsion temperatures within four to five degrees of the cooling water temperature. Refrigeration is therefore required only when the plant cooling water temperature is above approximately 80 deg. F. Based on representative refinery utility costs, the total direct operating cost including labor is only four to five cents per barrel of charge for a single stage operation of the type shown in Table IV. This operating cost is far lower than that usually encountered in conventional sweating. The operating cost of 10.4 cents per barrel for rerunning the foots oil shows a saving over conventional methods of recovering this wax.



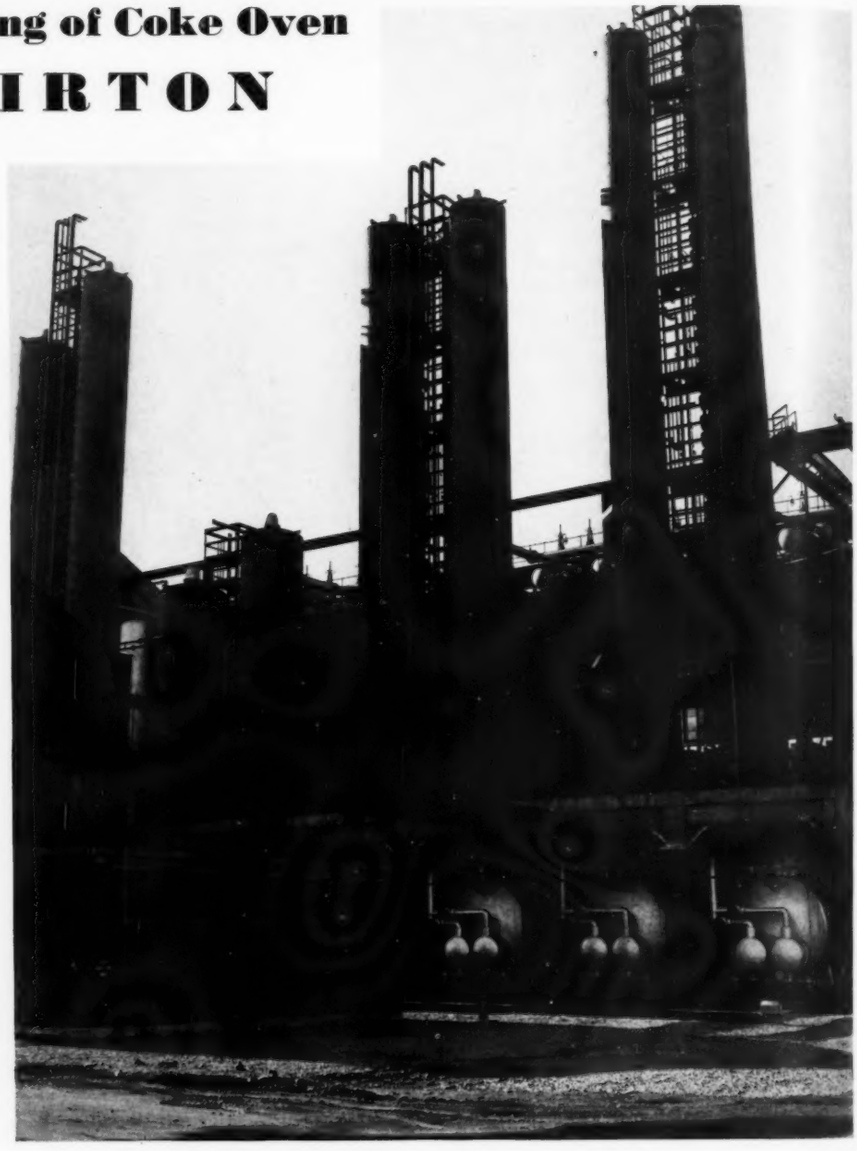
The pilot deoiling unit where the first new process of its kind in 20 years was developed.



Continuous Processing of Coke Oven Light Oil At CLAIRTON

By H. W. Seyler

Assistant General Superintendent in charge of Coke Plant Operation



While Broad Research and Development Work Promise to Establish Petroleum as the Chief Source of Toluol, Xylol and Solvents, the Exigencies of National Defense Require Greater Efficiency from the World's Largest Plant for Production of the Important Military Fractions as By-Products of Coke Oven Operation in the Steel Plant of Carnegie-Illinois.

PRIOR to the installation of the new continuous refining unit at the Clairton by-product coke works of the Carnegie-Illinois Steel Corporation the entire production of coke oven light oil was processed by batch distillation. The fractionating equipment consisted of 18 crude and pure stills all of the same design—and although slightly different in capacity, the stills were used for the separation of light oil into crude fractions as well as for the production of pure products. This plant, aside from lacking capacity for the production of maximum yields of commercially pure products, was also inadequate in fractionating efficiency for the production of highest quality products.

In the following description an attempt will be made to point out the various reasons for the installation as well as to give a fairly complete description of the function of the equipment and operation of the plant.

During recent years the trend in demand for light oil products has indicated gradual progressive changes towards pure products of higher quality, together with more limited specifications for the semi-refined products in order to meet individual requirements. These changes have necessitated various alterations in the refining process so that the maximum in fractionating capacities is required.

It is, therefore, because of these changing demands and the lack of fractionating capacity and efficiency in the former plant that a program of modernization was initiated.

In a study of the modernization program, due consideration was given to the continuous process since it was felt that this method offers many economies in operation that are not available in a batch distillation process and in considering the advisability of installing a continuous plant, it was found that sufficient quantities of light oil were available at low rates of coke plant operation to insure reasonable periods of continuous processing and at the same time permit a plant which would be of sufficient capacity to refine all of the light oil produced at full operation of the coke plant.

Furthermore, it will be noted from the general plan of refining light oil at this plant that the procedure is well adapted to a continuous distillation process.

The method consists of recovering the light oil from the absorbent oil as one fraction. The crude light oil is subjected to a fractional distillation to produce as individual distillates, forerunnings, a crude benzol cut, in addition to a broad fraction containing the benzol, toluol and xylol, and a residue consisting of higher boiling solvents, wash oil and naphthalene. The residue is subjected to a final distillation for the recovery of higher boiling solvents and the crude benzol, toluol, xylol fraction is acid treated for the polymerization

of unsaturated oils. The acid treated material is then redistilled for the recovery of the various components.

The processing of light oil, both in the old equipment as well as in the new plant follows this procedure, except that the replaced plant was complete batch rectification while the new installation is almost entirely continuous.

ARRANGEMENT

The continuous plant has been installed as an addition to the building which houses the last installation of batch stills and is so arranged that access can be gained from the new plant to either this building or to the tank house which is located along one side. The reboilers and rectifying columns have been located on the opposite side of the building from the tank house so that the building housing the transfer, controlling and cooling apparatus is located at the geographical center between the producing equipment and the storage tanks. In the continuous process the main body of the plant has been divided into two separate and distinct units. The crude product separation is effected in three stills referred to as crude stills and known as units, one, two and three, while the pure products are recovered in the remaining five stills known as units four to eight inclusive.

The continuous plant consists of eight stills of varying sizes and capacities and each unitis fitted with all necessary pumping and transfer apparatus, decanters, liquid level controls. flow meters and all auxiliary equipment for measuring temperature and pressure.

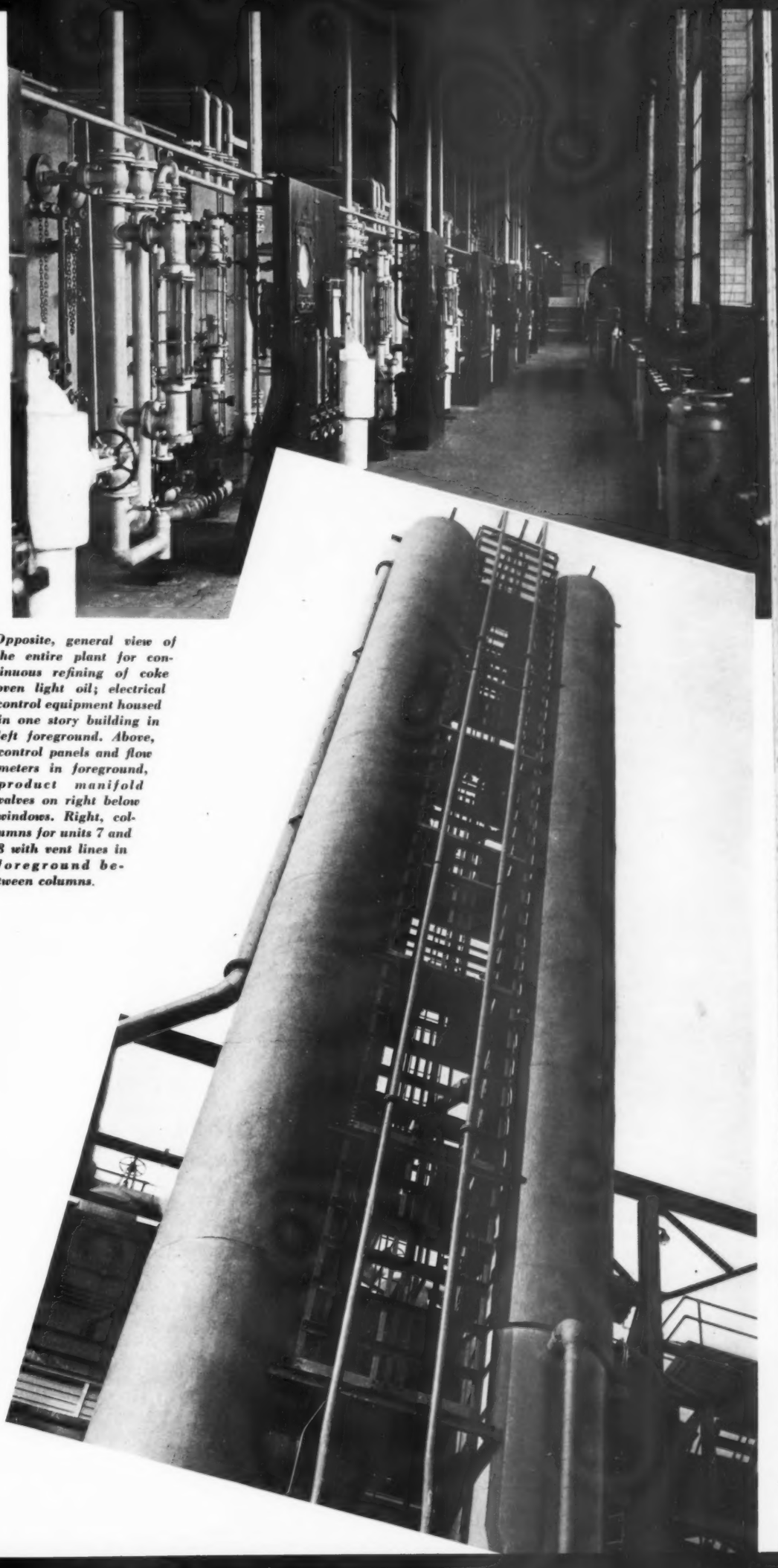
In the design of the plant the principle of centralized control has been utilized to an extent that it is possible for an operator stationed at the control floor to observe and regulate the performance of the entire plant. This control room is located on the second floor and contains all of the instruments for plant control as well as the various other equipment, such as decanters, product receiving tanks, etc., which must be under constant vigilance during operation.

The pumping and transfer apparatus for the products from the reboilers in addition to the main feed pumps, as well as a continuous water strainer and air compressors have been installed on the first floor while the condensing and cooling equipment is located on the roof.

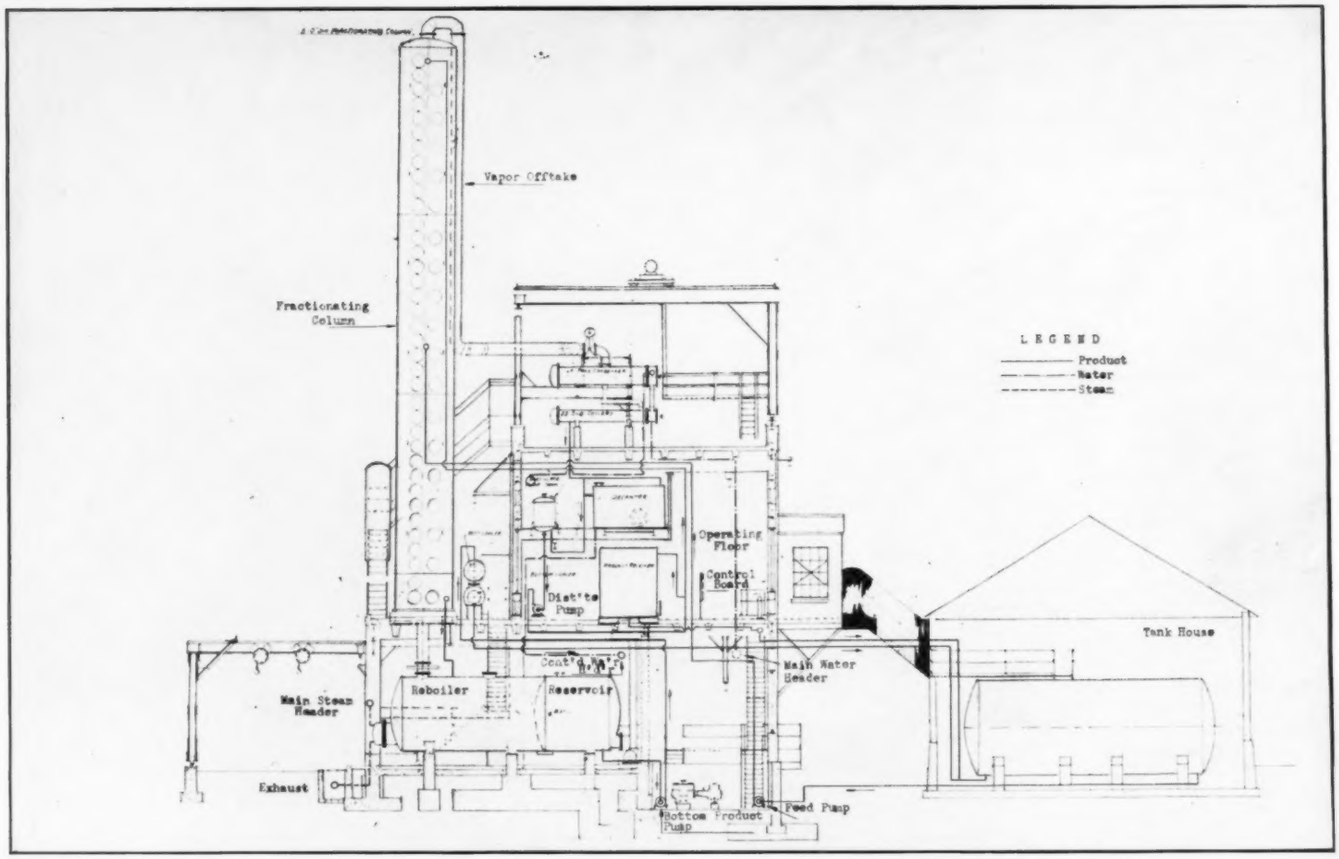
With a few exceptions, each unit in the plant consists of a reboiler or base heater and a rectifying column, which in turn is connected with condensers and product coolers followed by decanters and pump tanks. These pump tanks are followed in some cases with individual product tanks. This applies to the pure unit only as the products from the crude unit are discharged into large storage tanks.

The cross sectional diagram shown as Figure (1) will illustrate the relative positions of the various pieces of equipment.

The reboilers or base heaters vary proportionally in size as well as capacity and with one exception all are placed so that the longitudinal centerline is at right angles with the base of the column. They consist of cylindrical tanks and their foundations are located at yard level. The reboilers on the units in which



Opposite, general view of the entire plant for continuous refining of coke oven light oil; electrical control equipment housed in one story building in left foreground. Above, control panels and flow meters in foreground, product manifold valves on right below windows. Right, columns for units 7 and 8 with vent lines in foreground between columns.



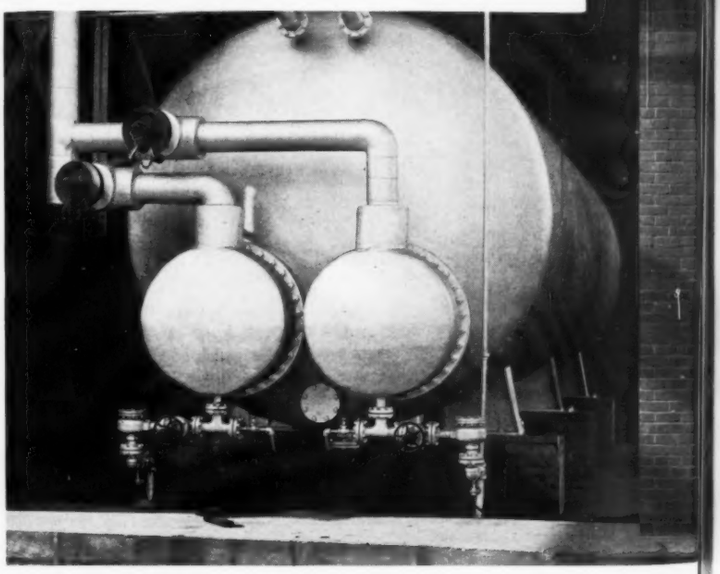
the bottom product is to be transferred to the succeeding fractionating tower have been divided into two sections by a solid partition wall and the two compartments are interconnected by an external pipe line at the base as well as vent lines on top. One compartment is used as a reboiler, and therefore, contains the entire heating element, while the other section is used as a surge or reservoir tank. Units one, five, six and seven have been provided with this compartment.

This reservoir or surge tank serves as the liquid level controlling tank in addition to other functions. One of these is that if there is an interruption of flow in some preceding apparatus, a better opportunity is afforded for the control of subsequent operations by maintaining this reserve of product. A further obvious advantage is realized also during start up periods. The reboilers on the remaining units, two and eight, are single compartment each, as the product from these are removed from the system.

Each reboiler heating section is equipped with two indirect heating units which vary proportionally in surface area depending upon the quantity of heat required and are so arranged that they can be removed from the reboiler for inspection and repair. Each reboiler heating section is provided with a separate steam supply and their operation is controlled by pressure regulating device installed in the vapor section so that the vapor pressure in the reboiler is used as the control for heat input. The regulator is arranged for either automatic or manual control and the operation in either case is controlled from the individual panel boards for each unit on the operating floor. This is a compressed air actuated device and an instrument has been provided for recording the operating pressure. Each unit is provided with this type recorder.

Above, Typical cross sectional arrangement of the continuous plant for refining coke oven light oil at the Clairton by-products coke works of the Carnegie - Illinois Steel Corp.

Right, end view of reboiler showing heater tube section with steam lines. The safety features which include rupture disc type explosion head are at left of pressure relief valve.



Indicating gauges have been provided on each control panel to show the level of the liquid in the heating and reservoir sections of the reboilers and this system has been augmented with the usual gauge glasses installed directly on the reservoir section.

Each reboiler has been provided with several safety devices. These devices consist of the conventional type pressure release valve as well as the rupture-disc type explosion head. An added safety feature is to be found in the method which is used for the control of heat. Since the rate of heat input is automatically controlled by the pressure of the vapors, any increase of pressure above that which has been set will automatically decrease the rate of heat applied.

Each unit is equipped with dual pumps for the transfer of product from the reboiler to subsequent equipment or storage. These pumps are single stage constant speed electrically driven centrifugal pumps and only one pump is normally used during operation with the other being retained as a spare. Their operation is controlled by a push button type remote control switch on the operating panel for each unit. This arrangement of push

button control is one in which a pilot light indicates which pump is operating and a feature has been installed whereby their operation is controlled from the operating floor only. This precludes the possibility of anyone accidentally or otherwise interrupting their operation without first consulting the plant operator. The only way in which interruption can be accomplished, aside from that on the control panel, is by releasing the main switch which controls the entire pumping equipment.

The rate of product removal from this equipment is regulated by the liquid level controlling device which has been installed in the reservoir section.

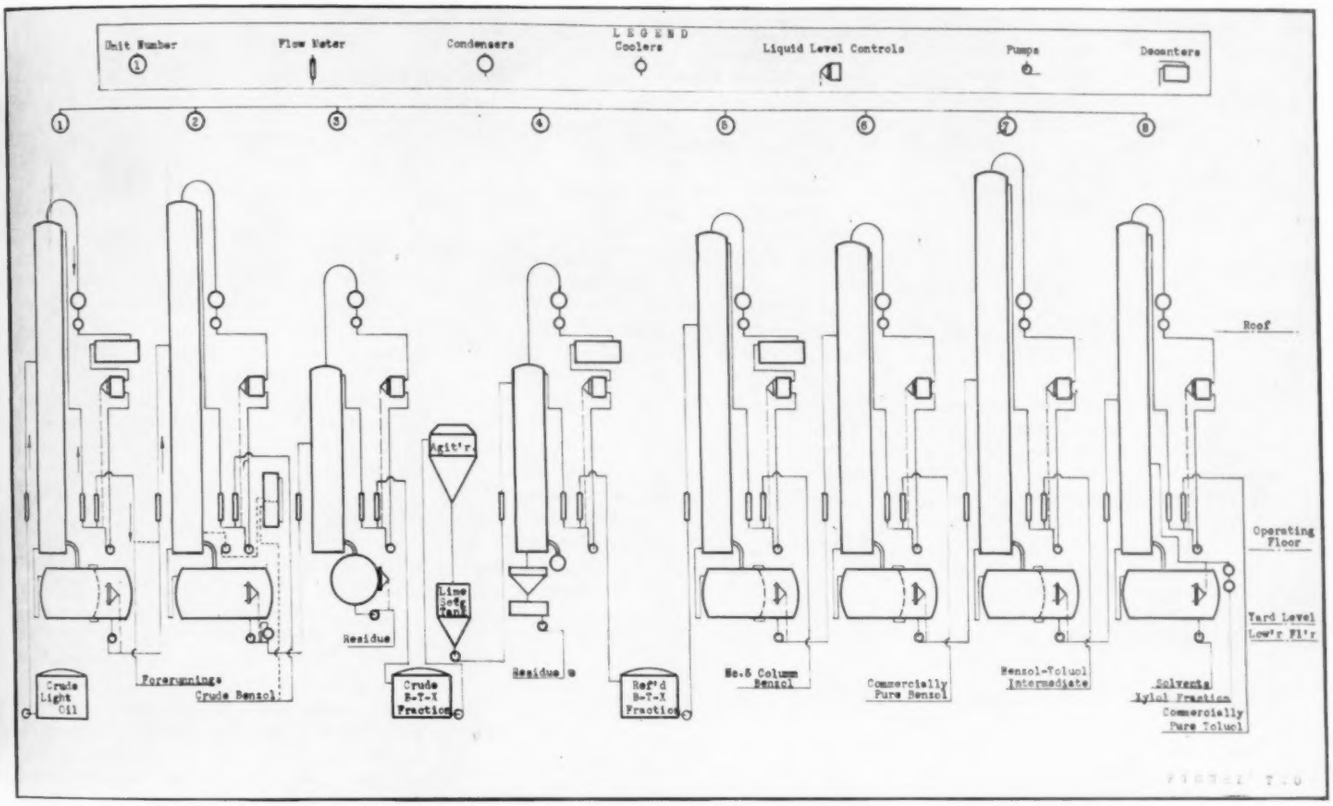
This device actuates a valve which is located immediately after the bottom product pumps. In this manner it is possible to use the constant speed electrically driven pumps and at the same time maintain sufficient liquid in the reboiler and also provide reasonably constant feed to the subsequent apparatus.

Liquid flow meters have been provided in those units in which the reboiler product is to be transferred to succeeding rectifying columns. These flow meters are located on the operating floor near the control panel for each unit; thus the rate of flow as well as any interruptions in operation can be immediately detected.

In the units in which the reboiler product is to be removed from the system, bottom coolers have been provided. This will apply to units one and two and their purpose is to provide continuous cooling of residual materials which are to be placed in storage. These coolers are the same general type as the coolers which have been provided for the condensed products and a detailed description of their construction and operation will be taken up later. The coolers are arranged with by-pass piping, so that in event the product is to be further fractionated in subsequent stills, the coolers can be by-passed in order to take advantage of the sensible heat.

The reboilers for unit number three, which is for the separation of heavy solvents and wash oil residue from the light oil, are arranged so that continuous removal of residue can be realized.

Unit number four, which is for the removal of polymerized material from the acid washed crude benzol-toluol-xylol fraction, is so arranged that the residue is separated continuously.



Schematic flow diagram of the plant at Clairton which produces industrial and nitration toluol, benzol, xylol and solvents as by-products in the manufacture of steel.

Each reboiler is connected with the rectifying column by a single vapor line in which has been inserted an expansion head. A self-sealing liquid return line has been provided also and in this manner the higher boiling materials are returned to the reboiler with the minimum of contact with the escaping vapors. The rectifying columns have been placed on one common floor immediately above the reboilers and are so arranged that the minimum of piping exists between the reboiler and column. The fractionating columns vary in height and diameter according to the rectifying demands. The shell of the column is constructed on welded steel plate and all interior fittings are of the same material. The material to be fractionated is fed into the column usually about midway between the base and top.

Two of these columns have been equipped with facilities for the removal of a side cut product. This applies to the column for units number two and eight. In unit number two the side cut product is collected on one of the lower trays and falls by gravity into a pump or liquid level control tank. The product is then pumped through the side cut cooler. Unit number eight is equipped with similar arrangements except that the product is removed from the column at a considerably higher level in the stripping section than that of unit number two.

A caustic washer is provided in the system for the continuous treating of distillate in event that it is found necessary to carry out such treatment to remove corrosion as indicated by the copper strip test.

The reboilers and rectifying columns as well as steam and product lines to the reboilers have been lagged with 85 percent magnesia, which in turn is protected with the usual water proofing materials.

Each column is provided with a vapor off-

take line, which is connected with the condensers and product coolers.

This equipment has been uniformly designed so that the greatest amount of one size material is used in order to facilitate repairs and maintenance and also to minimize inventories of replacement parts.

In order to accomplish this end it has been necessary to provide more condensers and coolers to the various units depending upon requirements and in all cases one extra has been added as a spare.

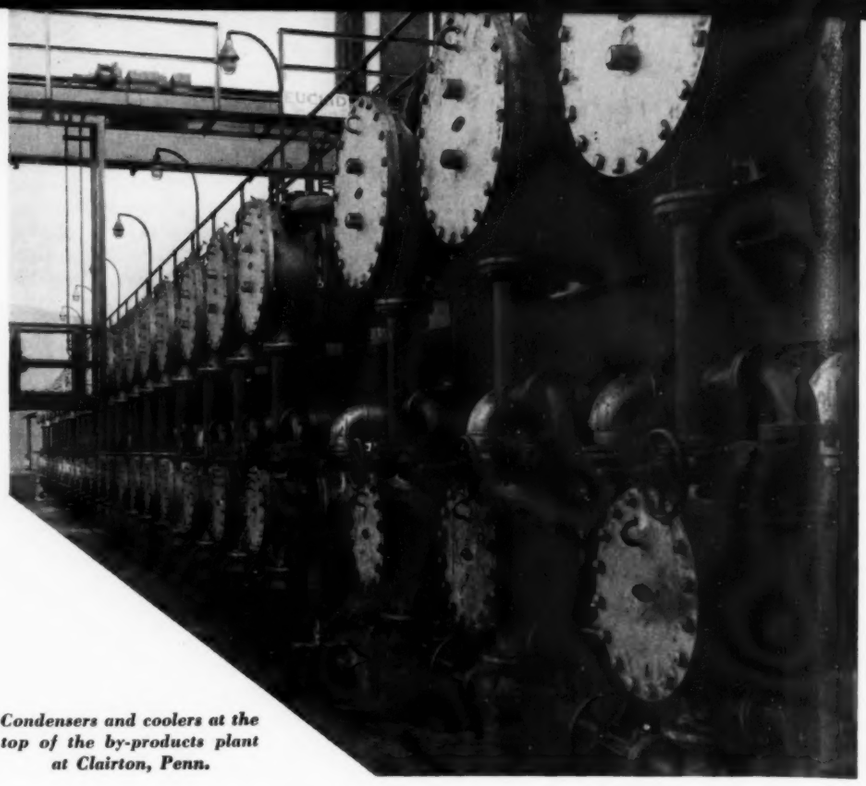
The condensers which have been installed are limited to two sizes, while there is only one size cooler in the entire plant. The condensers on all units, with the exceptions of those for units six and eight, are all four pass floating head type made up of one inch—13 gauge seamless black tube. The condensers on units six and eight are different from those previously mentioned in that they are six pass floating head type while the tubes are identical in size and material.

The purpose of the floating head is to allow for expansion and contraction during heating and cooling in order to eliminate strains on the tubes and tube sheets and at the same time facilitate repair and maintenance. Among the principal advantages which are claimed for this equipment is that it is possible to remove the entire tube bundle intact with the minimum of time and labor.

The coolers for the products from each of these condensers are placed immediately below the condenser and arranged so that the condenser products flow by gravity to the coolers, the outlet of which is partially sealed in order to submerge the tubes. The cooling and condensing water rises directly through the various passes in each piece of apparatus. The coolers are all two pass floating head type containing one inch—13 gauge seamless black tubes.

In both the condensers and coolers the cooling water circulates inside the tubes through the various passes and counter current to the flow of product, while the vapors and condensed liquid are contained between the tube and shell.

The product from the cooler then passes into either a decanter or liquid level control tank. In cases where water will be present in the distillate, a continuous decanter tank has been provided. Unit number one which is for the separation of heads from the light oil, together with unit four which is for the separation of acid washed residue from the light oil, as well as unit five for the primary distillation of pure products are fitted with this type decanter. This equipment is continuous in operation and is described as the fixed weir type in which the water separation is made by carrying a sufficient volume of liquid in the primary separation tank. The supernatant liquid will flow over the fixed weir while the water will be continuously removed from this section by a movable water level control. In this manner a sufficient head of liquid is maintained in order to effect a separation of water to a reasonably high degree while at the same time, water will be removed continuously.



Condensers and coolers at the top of the by-products plant at Clairton, Penn.

The pump or liquid level control tanks, as the name implies, serve a dual purpose, that is, they contain the apparatus for the control of liquid level in order to provide a constant head for the distillate pump, together with serving also as a surge tank. These tanks are provided with a liquid level control and their function is the same as those for the bottom product from the reboiler, in that they actuate a valve immediately after the distillate pump, thereby providing direct control of product flow. These tanks have been fitted also with facilities in the form of piping, such as overflow and venting lines together with water lines in order to serve as a purging medium during periods when repairs are necessary.

The product is then delivered to the distillate pump by gravity. Each unit is provided with dual distillate pumps, one of which is retained as a spare and their operation is controlled in a similar manner to the reboiler product pumps, that is, from the control panel of each unit. These pumps are situated on the operating floor and all are single stage electrically driven centrifugal pumps. The distillate is then delivered to a common line, the flow of which is divided near the control panel between two rotary liquid flow meters.

These flow meters are located immediately adjacent to the control panel for the individual unit and each is equipped with a manually operated valve for the control of distribution of distillate flow between reflux material and production. The reflux material is returned to the top of the column while the remainder of the product is removed and placed in storage tanks. In this manner it is possible to maintain accurate ratios between product and reflux and the quantity of material which will be removed as product in relation to that which is returned to the column as reflux will vary to a great extent depending upon the degree of rectification

Observations Which Can Be Made and Controls Which Can Be Maintained Over Plant Operation From The Control Floor

	Method of Measurement	Type	Item	Purpose Served
Flow Rates	Liquid Flow Meters	Indicating (G. P. M.)	1	Feed rate to individual units.
Flow Rates	Liquid Flow Meters	Indicating (G. P. M.)	2	Ratio of Reflux to product removal and flow rates of each.
Flow Rates	Recording Flow Meters	Indicating and Recording (G. P. M.)	1	Flow of materials to crude and pure units.
Flow Rates	Recording Flow Meters	Indicating and Recording (Lbs./Hr.)	2	Steam to Crude and Pure Unit.
Flow Rates	Recording Flow Meters	Indicating and Recording (G. P. M.)	3	Water to entire plant.
Pressure	Direct Reading Gauge	Indicating and Recording (Lbs./Sq. In.)	1	Reboiler pressure.
Pressure	Direct Reading Gauge	Indicating only (Lbs./Sq. In.)	2	Steam pressure.
Pressure	Direct Reading Gauge	Indicating only (Lbs./Sq. In.)	3	Air to air actuated devices.
Temp.	Potentiometer Pyrometer	Indicating and Recording (deg. F.)	1	Material in column above & below feed plate.
Temp.	Potentiometer Pyrometer	Indicating and Recording (deg. F.)	2	Material in column at top and base.
Temp.	Potentiometer Pyrometer	Indicating and Recording (deg. F.)	3	Material out of cooler.
Temp.	Potentiometer Pyrometer	Indicating and Recording (deg. F.)	4	Water out of condenser.
Levels	Pneumercator	Indicating only (In. of liquid)	1	Liquid in heater section of the reboiler.
Levels	Pneumercator	Indicating only (In. of liquid(	2	Liquid in reservoir section of the reboiler.
Levels	Direct Reading Gauge	Indicating only (In. of liquid)	3	Liquid in individual product receiver tanks.
Levels	Direct Reading Gauge	Indicating only (In. of liquid)	4	Liquid in liquid level control tanks.
Valves			1	Distribution of products from receiver to storage tanks.
Valves			2	Main steam supply to each unit.
Valves			3	Main water supply to each unit.
Miscellaneous			1	Remote control switches for operation of transfer pump.
Miscellaneous			2	Operation of continuous water filter.

*Note—G. P. M. = gallons per minute.

which is required. Each column has been provided with these rotary sight flow meters.

The distillate products which are recovered at this point will be, in the crude distillation unit, transferred directly to large storage tanks while those from the pure unit, with the exception of unit number five, will be collected in individual product receiving tanks. Unit number four has been equipped with four tanks of 2,900 gal. capacity each, unit number six has three with a capacity of 2,200 gal. each, while units seven and eight are fitted with three each, having an individual capacity of 1,250 gal. By this method it is possible to control and minimize the contamination of large quantities of specification products by obtaining definite information on chemical characteristics of the material prior to disposition.

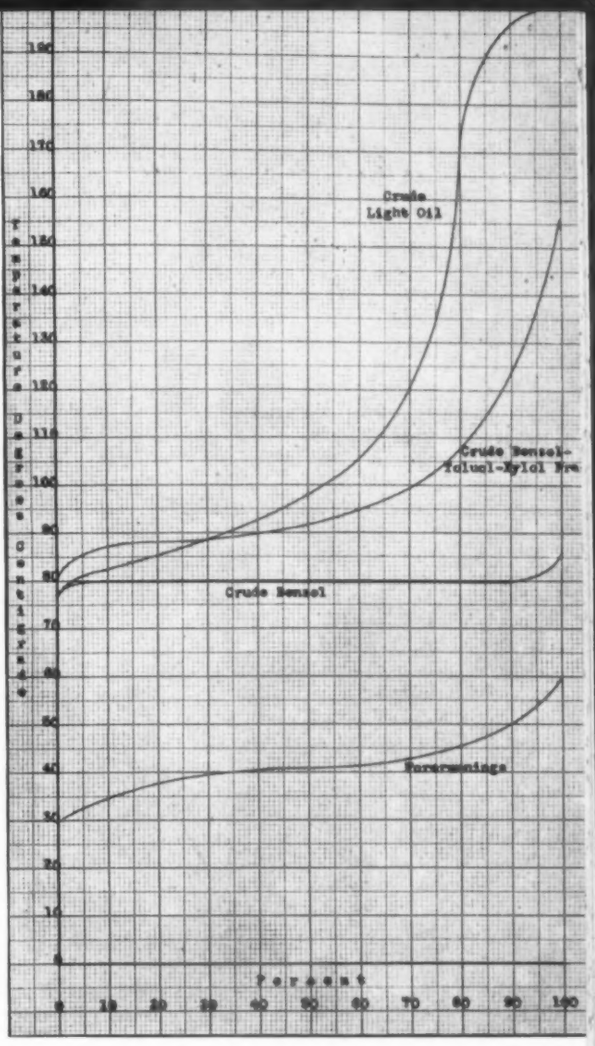
It has been mentioned previously that the operation of the plant is controlled from one central point and that control boards have been provided for each unit.

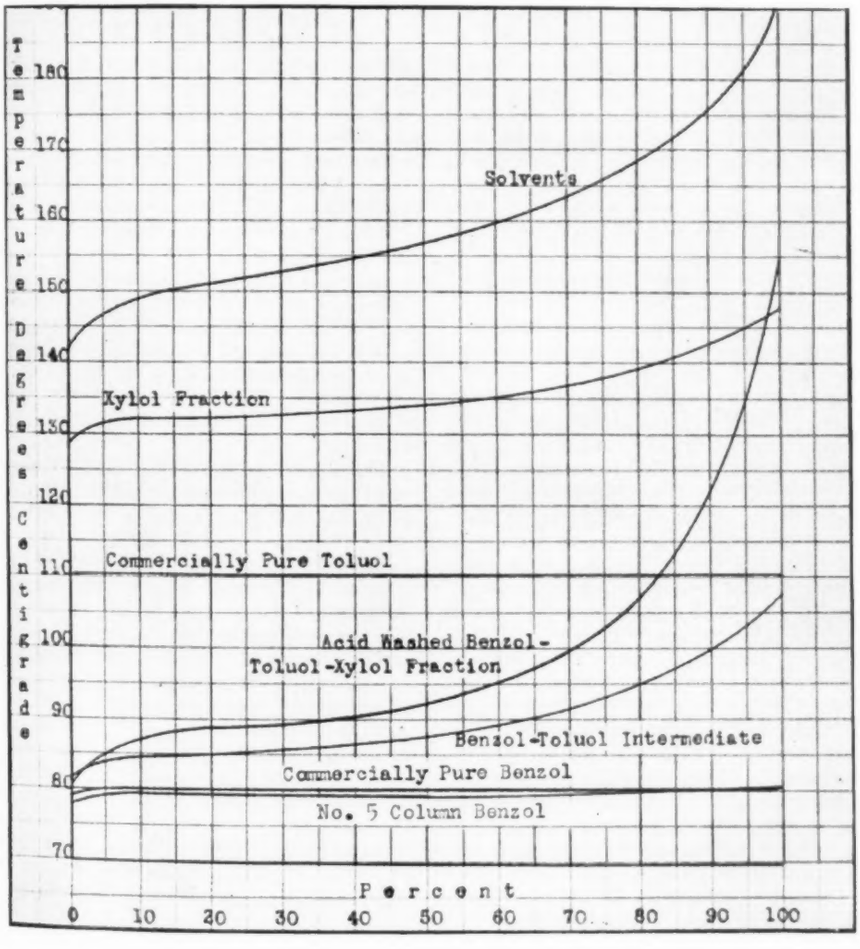
The various instruments which constitute a complete panel consist of a mercurial reboiler pressure gauge, the entire steam controlling apparatus including recording device for reboiler pressure and the gauge for indicating quantities of materials in the reboiler heating compartment and reservoir, as well as the remote control switches for operation of transfer pumps. These instruments have been described along with the various apparatus in which they function. In addition to the above, however, each panel has been provided with a temperature indicating and recording instrument for the observation and control of temperature at various strategic points in each system. This instrument indicates and records simultaneously the temperatures at six points in each unit, namely; the temperature of the material in the column above and below the feet plate, as well as the material at the top and base of the column together with the temperature of the distillate out of the cooler and the water out of the condensers. In addition to the above, the panels for units one, four and five are fitted with controllers to maintain a constant rate of feed. Since each of these units represents the starting point in the three main sections of the plant it can be seen that a means is necessary for control of flow rates. The instrument is entirely automatic and in addition to being both recording and direct reading, will maintain a definite predetermined rate of flow.

The main steam lines to both the crude and pure unit have been provided with orifice plates for the measurement of quantities of steam and recording instrument have been included on the control panels for units one and four. These instruments record the total steam consumption of the individual crude and pure units. Orifice plates are included in each of the steam lines to each reboiler although no recording or measuring devices have been installed. It is felt that, while at various times it will be necessary to measure the steam consumption of each unit, no advantage is to be gained by providing for constant measurement of these quantities and the installation of the orifice plates is included only to facilitate measurement when it is necessary. These recorders for units one and four are direct reading in thousands of pounds per hours.

The quantity of water which is consumed in the entire plant is indicated on a direct reading recording instrument. An orifice plate is included in the main water supply line and the recorder which is installed will indicate water consumption in gallons per minute.

As an aid to the centralized control principle, the control valves, wherever possible, have been installed in close proximity to the control panels. The manifold valves which control the disposition of materials from the pure unit in addition to the controlling valves for the crude and intermediate products are all situated at this location with the conse-





Right, distillation curves of crude light oil and products recovered in the crude distillation unit. Below, distillation curves of acid washed benzol-toluol-xylol fraction and products recovered in the pure distillation unit.

quence that at no time will it be necessary for the operator to lose sight of the entire operation for any sustained period of time.

The itemization shown in Figure 5 will further illustrate the observations which can be made and control which can be maintained over plant operation from either the main control panel for each unit or within a relatively short distance from this panel on the operating floor.

In addition to these recording instruments the various pieces of individual equipment have been provided with temperature and pressure gauges. Among these are the dial type thermometers which are installed on each condenser. It has been mentioned that a recording thermometer has been provided to indicate the temperature of the outlet water from the condensers. This temperature applies only to the outlet water from the bank of condensers for each unit, while the direct reading dial thermometer is used to indicate individual condenser performance and provide ease of reading. The water outlets from these condensers are located considerably above the floor level and the installation of the conventional type glass tubing thermometer would have been of little or no value.

The regulation type mercurial thermometer as well as dial type pressure gauges have been installed at various points where it is felt they would be an aid to plant performance and efficiency.

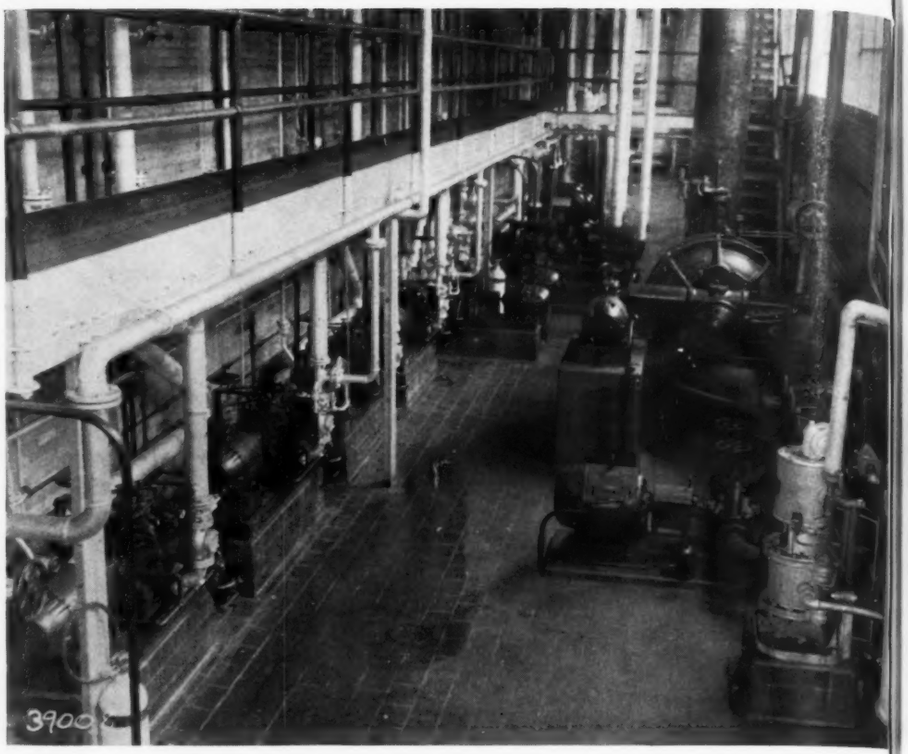
CRUDE UNIT

The general plan of operation of the unit is to effect a separation of the crude light oil in units one, two and three, inclusive, into crude forerunnings and crude benzol as required, in addition to a broad fraction containing benzol-toluol-xylol for subsequent recovery of pure products after acid washing and a residual fraction containing high boiling point solvents, wash oil and naphthalene.

The flow diagram shown on page 91 illustrates the general recovery scheme for the plant.

This is accomplished by pumping continuously the crude light oil as recovered by direct steam distillation of the benzolated wash oil into the first column at a rate of 5,000 to 6,000 gal. per hour. A distillate fraction, commonly called forerunnings, is removed from the light oil which contains carbon bisulphide and highly unsaturated hydrocarbons as the first step in the distillation process. The light oil is then transferred from the reboiler and fed into the second unit where a portion of the benzol is distilled over and reserved as a crude fraction. The residual oil is transferred from the reboiler of the second unit to unit number three for the separation of a crude benzol–toluol–xylol fraction from the heavy solvent and wash oil.

An alternate method is provided for the operation of these units, in which a crude benzol fraction containing all of the forerunnings can be removed from the light oil in the first unit, in which case unit number two will effect the separation of forerunnings from the benzol; the forerunnings being recovered as an overhead product and the crude benzol as a side stream near the base of the column.



Looking down on the lower pump room and the bottom product transfer pump, air compressor and water conditioning apparatus.

This method of operation is indicated in the flow chart by a broken line. Under this method of operation the residual oil in number one unit provides the feed for the third unit and the crude benzol-toluol-xylol fraction will be recovered as previously described.

If it is desired to discontinue the production of this crude benzol fraction, or to convert the entire available quantities in the light oil into pure products, the operation of the unit can be changed so that only a three product separation will be made, namely; crude forerunnings and a crude benzol-toluol-xylol fraction as distillates and the heavy solvents, naphthalene and wash oil as residue.

The operation of the unit under these conditions will be materially changed so that only two of the existing units will be used. This procedure will remove the low boiling compounds as a distillate in the first columns and transfer the reboiler material into the third unit. In this case the function of the third unit will remain the same as previously described.

The distillation curves for the crude light oil feed and distillates recovered from the crude distillation unit are shown in Fig. 3.

The crude distillation plant has been designed with sufficient capacity to refine all of the light oil produced when the coke plant is operating at full capacity and to assure wide enough range of operation in order to effect the division and quality of crude products which have been described previously.

PURE UNIT

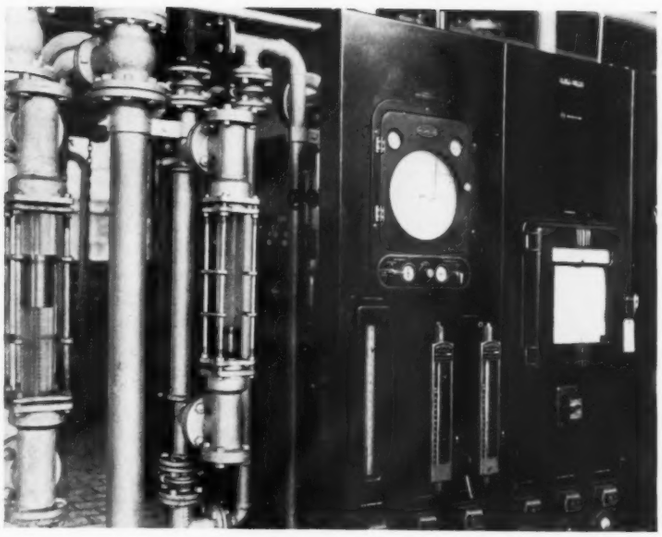
The operating procedures for the pure unit are as follows: The crude benzol-toluol-xylol fraction which is recovered in the crude unit is acid washed by batch operation. This is an intermittent process and is part of the old plant to which various improvements have been added, such as settling tanks in order to facilitate the removal of suspended material.

The product from these settling tanks is fed into fractionating tower of unit four near the top and the separation which is offered is the removal of the overall fraction containing the acid washed benzol-toluol-xylol and solvents as the distillate and polymerized residue as the material from the base of the column. The residue is removed through the decanters while the distillate is transferred to one of three 35,000 gal. tanks.

The purpose of these tanks is to serve as surge take-up and at the same time maintain sufficient storage of materials to insure a uniform feed to the succeeding pure product units. Since the remaining units from this point are continuous in operation, in that the residue from each reboiler is used as feed to its successor, and since the uniform balance of product removal, in relation to feed must remain in constant equilibrium, in order to obtain maximum product quality, it can be seen that uniform feed to this unit is of utmost importance.

Arrangements have been provided for feeding the distillate product from this column directly to unit number five; although for the reasons previously stated this method is not desirable, it could be used in case of necessity.

The quality of product which is recovered from number five still will, of course depend



General view of control panel and flow meters in the Clairton, Penn. plant of the Carnegie-Illinois Steel Corporation.

upon the character of the light oil; and the function of this column is to remove the low boiling constituents from the washed benzol-toluol-xylol fraction prior to production of pure benzol in column six. It has been found that this product is free from corrosion as indicated by the copper strip method.

The product from the reboiler of this unit is transferred directly into the column of unit number six, the function of which is the production of high quality pure benzol. The unit has been found capable of producing a product with a boiling range of less than one degree centigrade without difficulty in addition to a high freezing point. The benzol is neutral in reaction, the corrosion test negative and the wash test has been found to be equivalent to Barrett number one or less.

The material which collects in the reboiler will obviously contain all of the toluol, xylol and higher boiling homologues together with a small amount of benzol and intermediate fractions. The purpose of the following unit, therefore, is to remove the intermediate material which boils between the benzol and toluol fraction in order to provide for the recovery of toluol of high purity in the next succeeding unit. It can readily be seen that the character of the distillate from unit number seven will be subject to considerable fluctuation in the boiling range and may vary between 10 and 30 deg., depending upon the character of the benzol desired from the previous column as well as the toluol desired from unit number eight. This number seven unit, therefore, is for the removal of the intermediate fraction and this is accomplished in the same manner as has been described for unit six in that the material is fed into the unit near the center of the column and the intermediate product recovered as a distillate.

The material from the reboiler of this unit number seven which consists of toluol, xylol, etc., is transferred to unit eight for the removal of commercially pure toluol as a distillate and a xylol fraction as a side cut, while the material in the reboiler will consist of part of the xylol fraction in addition to higher boiling solvents.

The quality of toluol which has been produced has been found to have less than one degree boiling range, is neutral in reaction, free from corrosion and has a low Barrett wash test.

In the operating scheme previously shown the operation of the pure unit for the production of the optimum quantities of commercially pure benzol and toluol in addition to the recovery of a xylol fraction as a side cut product from unit eight has been described.

The distillation curves shown in Figure 4 indicate the boiling range of the various products recovered in this pure distillation unit.

The principal advantages claimed for the continuous plant which have been installed are as follows:

(1) Speed of production by which it is possible to produce relatively large quantities of high purity products in the minimum time.
(2) Possible to produce the optimum quantities of pure products—without the necessity of reprocessing intermediate fractions.
(3) Concentration of plant and centralization of controls which result in advantages such as. ease of supervision, operation, etc.
(4) Elimination of contamination of products due to constant production of one grade material from one still.
(5) Economy of operation such as conservation of steam and water.

ADDITIONAL FACILITIES

In addition to the fractionating facilities which have been provided on the continuous unit, it was considered advisable to rehabilitate some of the existing batch stills which were part of the old equipment. This was accomplished by replacing the existing dephlegmator and condensers with the same type condenser which has been installed in the new plant. The equipment was further modernized by the installation of decanters, liquid level control tanks, product pumps and rotary flow meters. This apparatus was added to the existing columns and still tanks, while a fifth still was fitted with an entirely new column in addition to the above equipment.

It was felt that the additional facilities would be of considerable advantage for the production of special products in order to meet individual specifications.

GENERAL

The discussion thus far has been limited to the description of the apparatus and its function with regards to production while certain other features have been installed in the plant which have been included in the interest of economy and maintenance.

Traveling cranes have been provided in order to expedite the removal of tube bundles from the reboilers as well as the cooling and condensing equipment. There are two such cranes, one of which is immediately adjacent to the reboilers while the other is installed over the roof of the building. The crane which has been installed for the removal of tube bundles from the reboilers, is that in which one leg is supported on a track which in turn is supported on the foundation pillars for the floor on which the fractionating towers are located, while the other leg is supported on a track at yard level at a sufficient distance away so that it is possible to remove the entire tube bundle by the movable device on the trolley. The crane which is over the building is for the repair and maintenance of the condensers and coolers and both foundation legs are supported on the side walls of the building. Both cranes travel the entire length of the building.

In order to insure that the plant will be guaranteed a supply of water which is reasonably free from silt and other materials which usually collect in condensing and cooling equipment a continuous filter has been provided in the main water supply line.

The transfer equipment is electrically driven and the main controlled units for the operation of the remote control system have been installed in a separate building at a sufficient distance from the continuous plant in order to eliminate any fire hazards from this source. The motors are all the latest type explosion-proof and all electric lighting equipment including switches and lights are all of the accepted standards required for hazardous atmospheres.

The entire plant including rehabilitation of the existing equipment has been designed by the Semet-Solvay Engineering Corporation in conjunction with the engineering and operating forces of the Carnegie-Illinois Steel Corporation and special consideration has been given to the economics of production, ease of operation and the installation of safety measures for the protection of the personnel and plant.

The author wishes to acknowledge the assistance of Mr. F. M. Thatcher, Chief Chemist, and Mr. F. M. Becker, Assistant to Chief Chemist, together with members of the Clairton Works organization of the Carnegie-Illinois Steel Corporation, in the preparation of this description.

DOWTHERM - A New Development for Indirect Heating

By J. C. Glen
Foster Wheeler Corp.

Developed for General Industrial Use, Close Temperature Control Characteristic of Dowtherm May Open Wide Field of Application in Newer Refining Processes.

DOWTHERM is a mixture of diphenyl and diphenyl oxide developed for use as a high temperature, low pressure, heating medium. This substance has proved satisfactory and economical for vapor phase heating in the temperature ranges higher than those economically possible with steam. Many applications have been developed for the oil industry, especially in solvent refining and in the manufacture of high octane motor and aviation fuels where extremely close temperature control is a primary requirement. Since Dowtherm vapor gives up its heat upon condensation, temperature control is positive and is easily obtained. As long as there is a supply of vapor to the heater or reboiler, the temperature in the unit remains constant. It is also possible to work with relatively low temperature differences inasmuch as most of the heating effect is due to the latent heat of condensation.

Dowtherm has a boiling temperature of 500 deg. F. at atmospheric pressure and a temperature of 700 deg. F. can be obtained with an absolute pressure of only 103 lb. per sq. in. Temperatures as low as 350 deg. F. can be obtained by vacuum operation. This temperature range covers most refinery processes. Dowtherm is a stable compound at temperatures up to 750 deg. with the result that there is no deterioration of product and operation is simplified by the elimination of coking and cracking, both of which are constant sources of annoyance in early refinery methods involving the circulation of gas oil or other distillates.

When Dowtherm is used as an indirect heating medium, a single vapor generator can take care of all of the heating requirements of a single refinery process by producing vapor of the desired pressure and temperature for the highest temperature requirement. Throttling of vapor through automatic reducing valves reduces its temperature and pressure for all other indirect uses in the system.

Dowtherm condensate is a clear liquid which will not foul the heating surfaces of preheaters, exchangers and reboilers with the result that maintenance costs are negligible. Since Dowtherm is used in vapor form, heat transfer rates are high per unit of heating surface and heaters are small enough to permit placing them economically in most advantageous positions. This reduces piping cost for oil lines and eliminates much of the pumping required when heaters are direct fired or when a liquid heating medium is used.

Two arrangements are generally available. The entire flow may be by gravity if the indirect heaters can be placed at sufficient elevation to permit gravity return of Dowtherm condensate to the Dowtherm vapor generator as shown in Figure Three. Such an arrangement operates the same as a domestic steam boiler in that no feed pump

Figure 1: Simplified flow diagram of 100 octane blending stock plant showing reboilers and preheater heated with Dowtherm vapor.

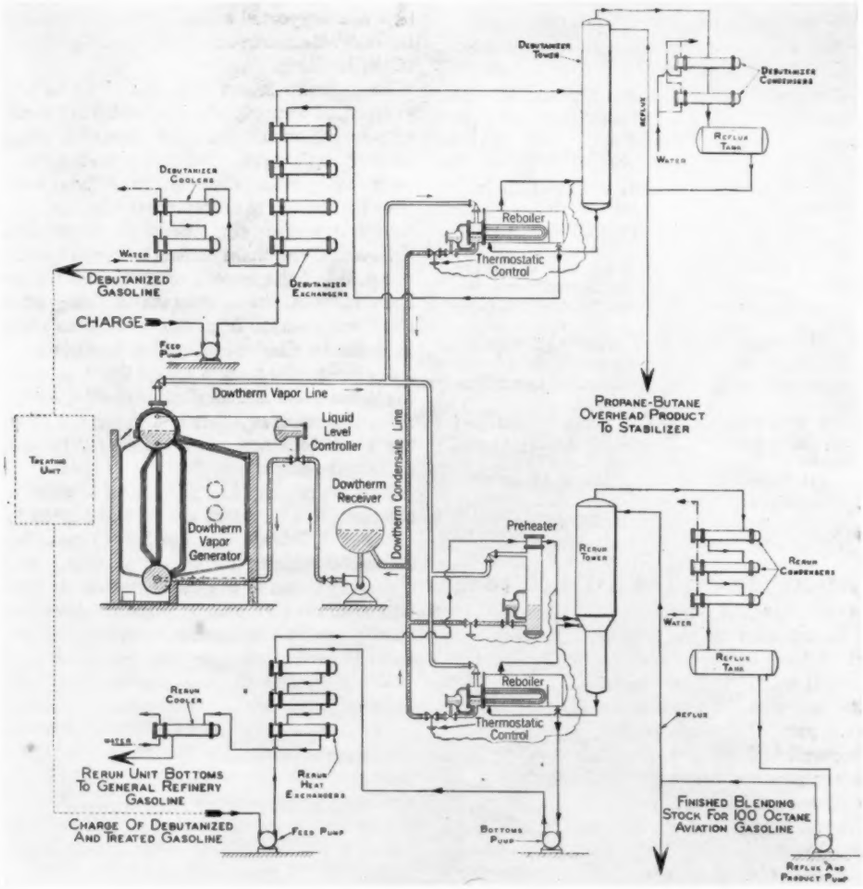
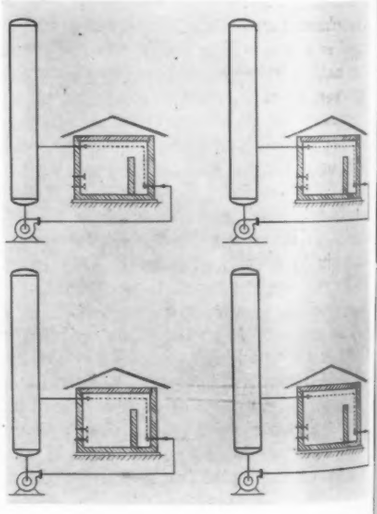


Figure 2: Comparison between a poly plant preparation unit using direct fired heaters and Dowtherm indirect heaters.



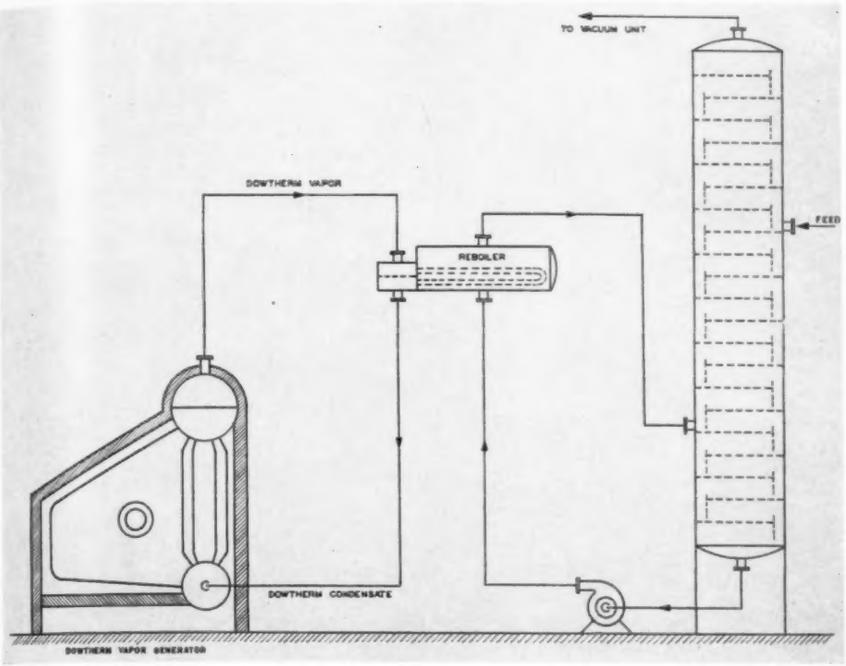


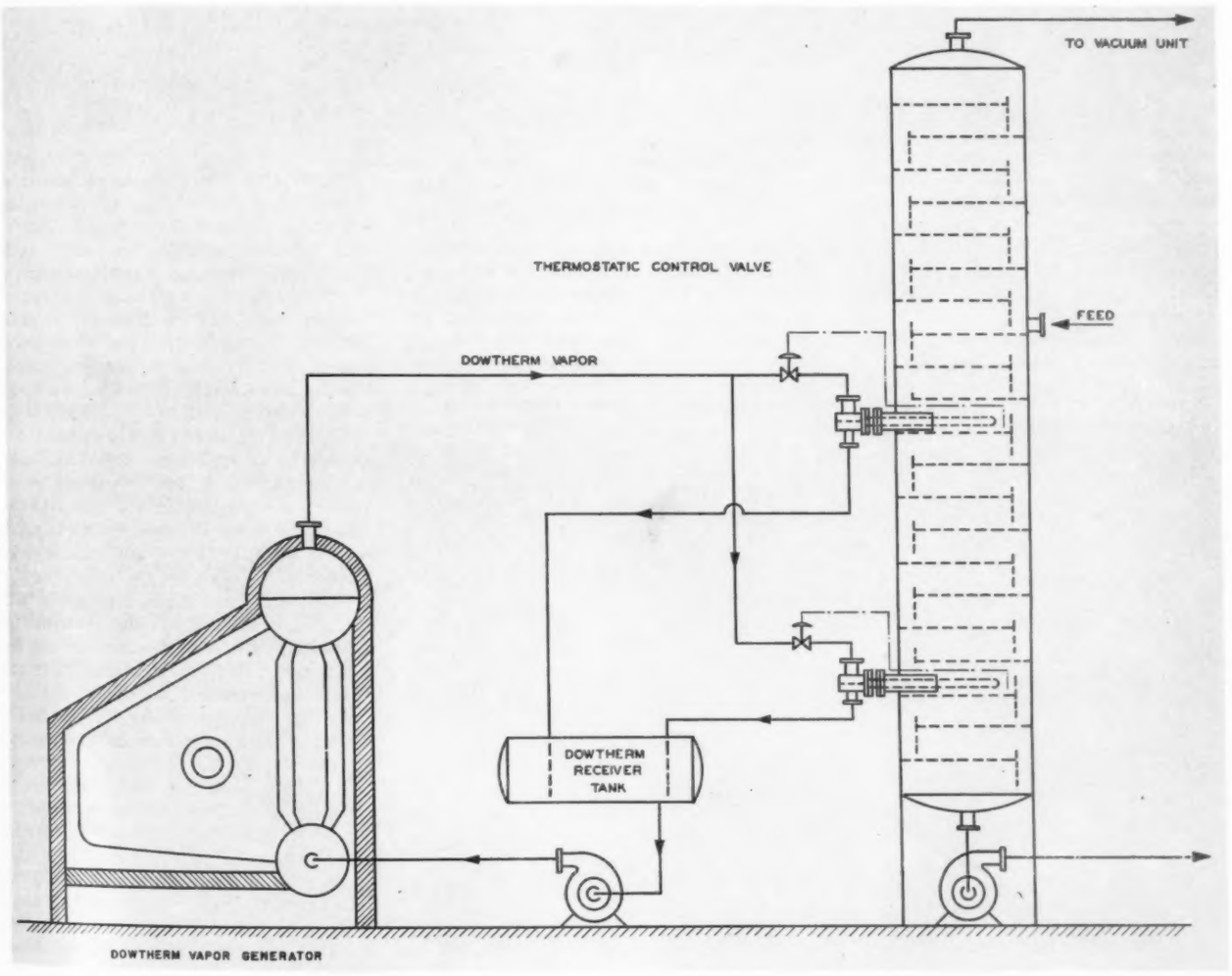
Figure 3.

is required. The other arrangement involves the use of a condensate tank placed at ground level for receiving condensate by gravity, from all of the heaters using the Dowtherm vapor as shown in Figure Four In this case a small return pump is used to maintain proper level in the vapor generator taking condensate from the condensate receiver.

Temp. deg. F.	Pressure p.s.i. abs.	HEAT CONTENT B.t.u./lb. Liquid	Latent	Total	Sp. Heat	DENSITY lbs./cu. ft. Liquid	Vapor
53.6.....	0.4	164	164	0.37			
100.....	1.8	158	176	0.40			
200.....	6.0	150	210	0.44	62.5	0.0012	
300.....0.74	10.8	142	250	0.50	59.6	0.012	
400.....4.1	16.2	134	296	0.57	56.7	0.068	
500.....15.0	22.2	123	345	0.63	54.1	0.28	
600.....43.0	28.8	110	398	0.66	50.4	0.88	
700.....103.0	35.8	97	455	0.68	46.9	1.7	

The Dowtherm vapor generator is built on the order of a modern steam boiler and is illustrated in Figures Six and Seven. It operates at a correspondingly high thermal efficiency. It is generally much more efficient than a direct fired oil heater or a heater for recirculating gas oil. The Dowtherm unit is likewise smaller and much less expensive to build. Figure Two shows an interesting comparison between a Dowtherm heated refinery process and the same process using four direct fired heaters. This process

Figure 4.



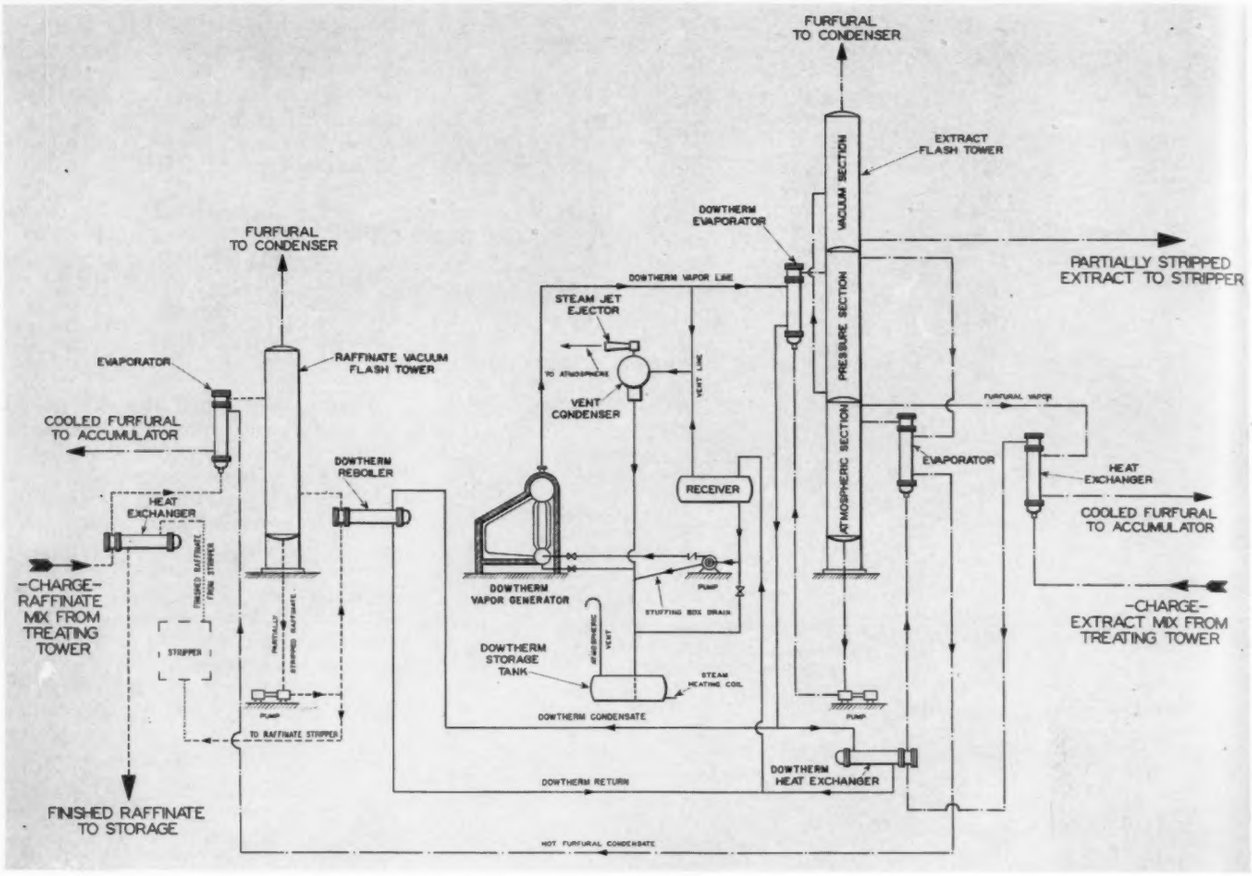
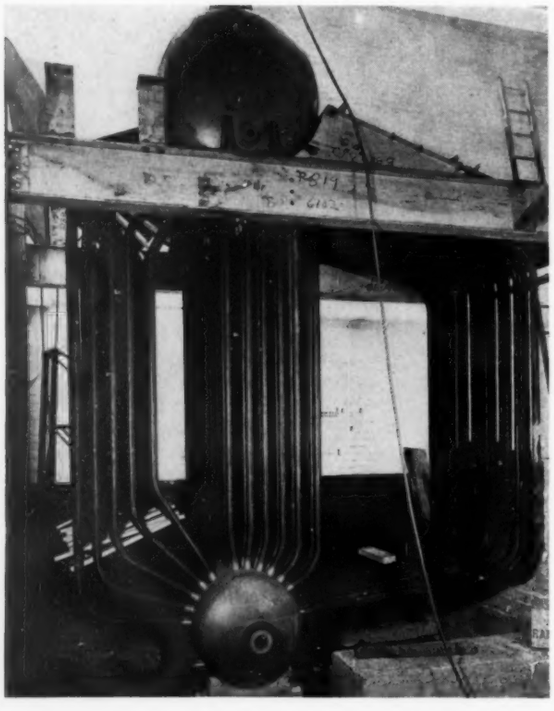


Figure 5: Arrangement of a furfural solvent refining process with Dowtherm indirect heating for hairline temperature control.

required a pressure distillate stabilizer, a reformed gas stabilizer, a depropanizer and a prefractionator with a total heat input of 36,000,000 Btu. per hour. Four direct fired heaters cost $80,000 to install and require the use of charge pumps for each heater with a daily power consumption of 1,350 k.w.h. The complete Dowtherm installation including vapor generator, accessory equipment and Dowtherm to fill the system, cost only $50,000 and requires no charging pumps since the reboilers were of the thermo-syphon type. In addition to the saving of first cost and saving in operating cost, a better product is obtained by the entire elimination of local overheating.

Figures 6 & 7: Construction view of Dowtherm vapor generator with tubes installed and a diagrammatic drawing of the same unit which has a capacity of 5,000,000 BTU per hour.



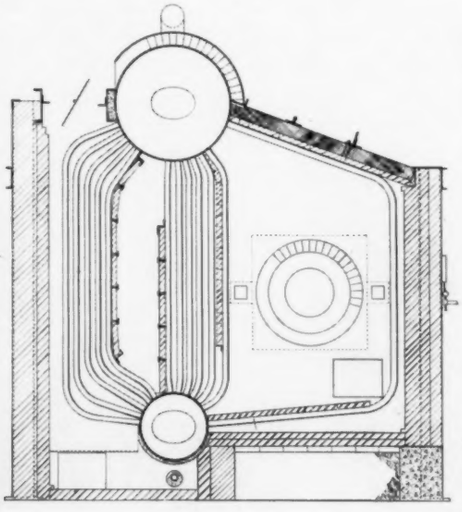
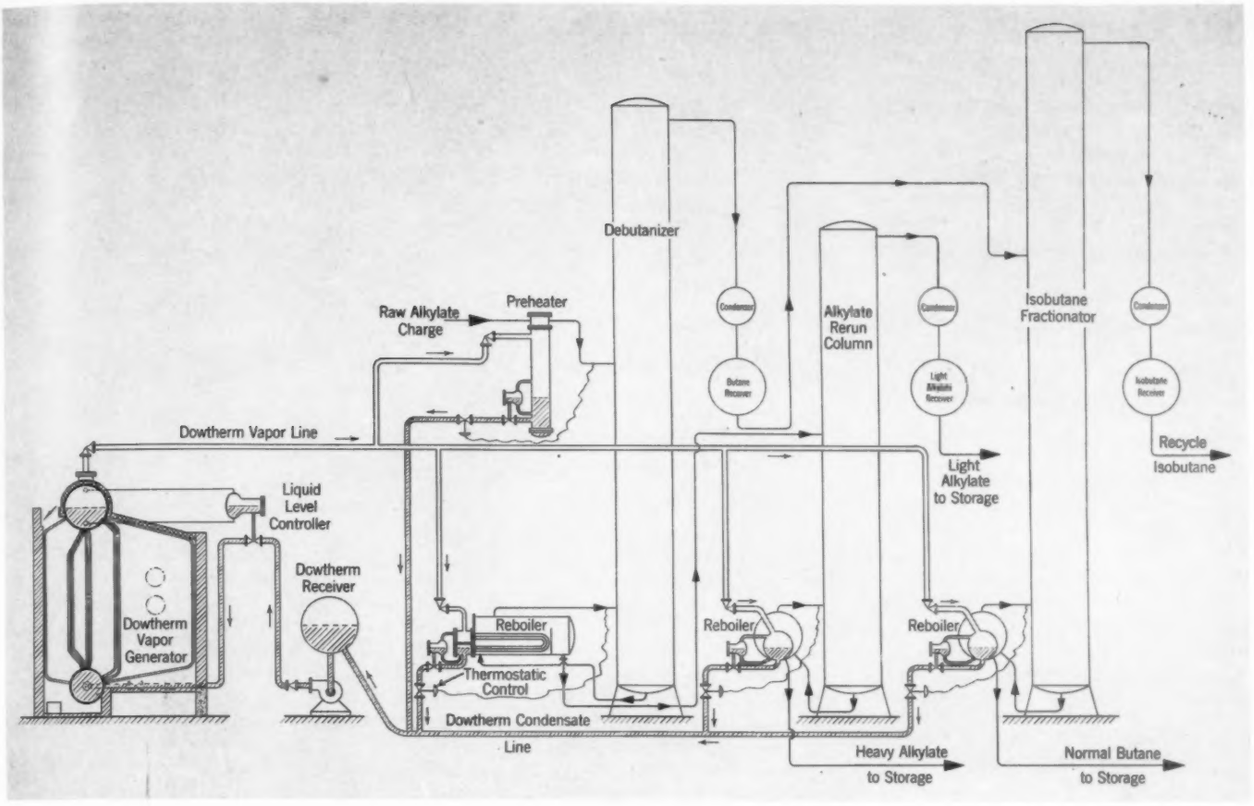


Figure One shows the application of a Dowtherm vapor heating system to a blending stock unit for the manufacture of 100 octane aviation gasoline. The reboilers on the debutanizer tower and rerun tower are both of the kettle type assuring a thoroughly stripped end product without danger of overheating. The charge for the rerun tower is preheated in a shell-and-tube type preheater also thermostatically controlled by flooding with condensate.

Figure Five shows the application of a Dowtherm system to a furfural solvent refining plant in which Dowtherm vapor is used in the evaporator and hot Dowtherm condensate from the evaporator is used as heating medium in the heat exchanger and reboiler.

There are some modern refineries where steam is generated at sufficient pressure to be used in many heating processes in the Dowtherm range, but nevertheless Dowtherm is preferable for several reasons in addition to the saving in equipment cost due to the lower operating pressure of Dowtherm equipment. The use of steam from a central plant requires long high pressure lines which are expensive and must be equipped with numerous expansion joints. After the steam is made available at the process site provision must be made for desuperheating since superheat would make hot spots in the heater that would cause local overheating. Finally steam taken from considerable distance is subject to variation in



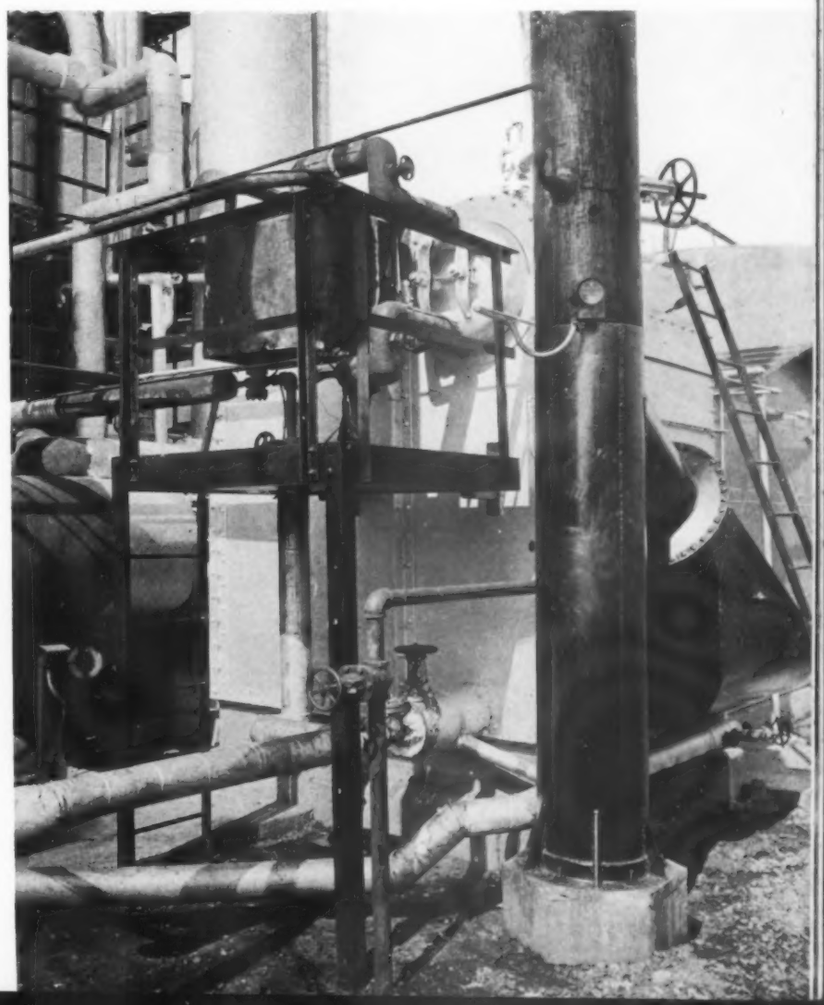
pressure. If the steam is generated at a nominal pressure of 600 lbs. per sq. in., it would leave the superheater outlet at a pressure varying from 570 to 595 lbs. per sq. in. depending upon load. In transportation of 1,000 ft. it is subject to a pressure loss up to 50 lbs. depending on amount drawn from the line at various points. Thus it is not unreasonable to expect a steam pressure at the process varying between 520 and 590 lbs. per sq. in. which gives a temperature fluctuation of saturated steam from 474 to 487 deg. F. A Dowtherm installation at the process site would not have a temperature fluctuation of more than plus or minus two degrees F.

Dowtherm vapor, as an indirect heating medium, is also superior to circulated hot oil. Since Dowtherm is used in the vapor phase the temperature throughout the heater or reboiler is uniform whereas the oil temperature drops as soon as heat is removed. Smaller quantities of Dowtherm are required with resultant savings in piping costs and lower equipment costs mentioned above. Circulated hot oil is usually at a temperature considerably above the flash point making it subject to fire hazard in case of leakage. Dowtherm on the other hand is slow burning. It is also nonpoisonous and inexpensive; the original charge in the system will last indefinitely without thickening or becoming scale or coke forming after years of service. The first industrial Dowtherm installation made ten years ago still shows no sign of deterioration.

The number of possibilities and arrangements of Dowtherm vapor to refinery processes is almost unlimited. Only a few of the numerous applications have been worked out but it would be a very simple matter to apply such a system to any process involving reboiling or indirect heating with close terminal differences. The product can be improved and costs reduced in almost every instance.

***Above, Figure 8:** Dowtherm vapor indirect heating system applied to an alkylation plant. Thermosyphon reboilers on each column and the preheater on the debutanizer are all heated with Dowtherm.*

***Right, Figure 9:** Dowtherm vapor generator installation in an Eastern refinery showing the small size of the Dowtherm unit and its simplicity. Operation of the Dowtherm generator is fully automatic.*



War Controls Course of Refinery CONSTRUCTION

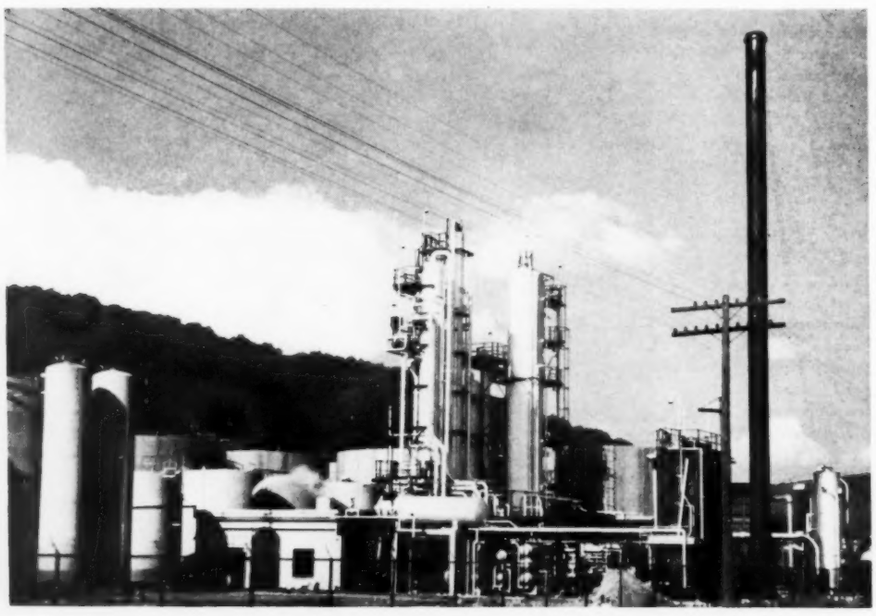
Probable Net Loss of Refining Capacity Outside U. S.—Acidulated Cracking in Russia—U. S. Refiners Adding Catalytic Processes, Increasing Capacities.

THE primary factor affecting the work of refinery construction and modernization throughout the world during the past year undoubtedly has been the wars in Europe and the Far East. In commenting on this situation, the Annual Refinery Issue of WORLD PETROLEUM for 1939, said:

> "Changes in supplies sources and trade routes caused by the war in Europe have directed renewed interest . . . to the location and capacity of refining plants which must be depended upon to process this crude into various petroleum products. Of the belligerent nations, neither Britain nor Germany has refining facilities adequate to supply their normal commercial requirements. France is somewhat better equipped in this respect. Its 20 plants have a total crude capacity of roundly 6,500,000 metric tons of crude annually. Germany's established facilities enable her to refine something over half her annual crude requirements, while the United Kingdom can process considerably less than half her peacetime needs."

These words were written shortly after the outbreak of hostilities. The fate of the refineries of Germany, France, England and Italy remains shrouded in mystery. Fragmentary, and unreliable reports speak of the destruction of a large part of the French refining capacity; numerous communiques refer to frequent bombing of German refineries and synthetic oil plants; beyond question, considerable damage must have been done to the refineries in Europe. Italian refineries have been bombed by the R. A. F. and recently reports have been received of the bombing of the Bahrein refinery in the Persian Gulf. No exact appraisal of the extent of this damage, nor of the steps that may have been taken to construct new refining capacity in any of these countries is now possible. How much of the 3,000,000 bbl. per day refining capacity that existed outside of the United States remains undamaged and in operation is of course a matter of conjecture: on the basis of reports received and making due allowance for the propaganda motives which inspire many of these reports it may be assumed that this 3,000,000 bbl. per day capacity has undergone a substantial net loss.

Against the destruction of refining capacity in Europe, may be placed, the completion of a large modern refinery in Eastern Venezuela and a considerable amount of work in increasing the capacity of the world's three largest plants, two of which are located in the Dutch West Indies and one in Iran. So far, no reports have been received that would indicate that these three plants have suffered any damage whatsoever, as a result of the hostilities. Obviously, no information as to the extent or type of work on these or other refineries outside the United States is available. It is simply an assumption that the exigencies of the present situation have led to work on these and other plants outside the United States designed to increase their efficiency and add to their total capacity.



Phenol extraction plant of the Kendall Oil & Refining Company charging 1500 bbl. per day for extraction of neutrals and bright stocks.

In common with the rest of Europe, practically no reports on actual refinery construction have come from the U. S. S. R. There is however, one report from the Soviet Union which may be of considerable significance for the future of the Russian refining industry. Professor Tchelinzev in an article published in INDUSTRIA for June 29, 1940 states that the method of cracking crude oil in the U. S. S. R. does not meet the demands of the highest standard of products, and is uneconomical because of the high rate of waste. He refers to the low yield of gasoline which he states is of the order 33-34 percent of the charged crude. He also calls attention to the low octane number of this gasoline which, without the addition of tetraethyl lead, reaches only 60 o.n.

After reviewing briefly the alleged shortcomings of the Houdry system which has become the subject of wide-spread interest among the refiners of the Soviet Union, Professor Tchelinzev refers to the system worked out by K. Dubrovaya several years ago in the U. S. S. R. and known as "Acidulated Vapor Phase Cracking". While the advantages of this system were not recognized by the officials of the Soviet oil industry when the process was first presented by Dubrovaya, Professor Tchelinzev now points out that acidulated vapor phase cracking is superior in many ways to the Houdry process and would be extremely important for the refining of crude oil from the Second Baku district. Crude oil from this area contains between 2.4 and 2.6 percent of sulfur which can be reduced to .04 percent when treated by the Acidulated Vapor Phase system.

According to the Professor, Dubrovaya's process yields 85-86 octane gasoline without the use of a catalyst; when a catalyst is added, it is possible to produce 91-92 octane gasoline. Among other advantages, Professor Tchelinzev refers to the fact that heating in this system is accomplished by air enriched with oxygen introduced into the reaction chamber, thereby avoiding the formation of coke; three reaction chambers are eliminated and there is no need to regenerate the catalyst at frequent intervals.

While the process is not fully described by any means, it may prove of considerable significance to the Russian oil industry at the conclusion of the war. It will be recalled that one of the obstacles encountered by the Russian refining industry was the production of a reasonably high octane, sulfur-free gasoline. These statements of Professor Tchelinzev would indicate that a process is now available in Russia that does not involve high installation or operating costs and which

Air view of the Hancock Refinery at Long Beach, California.

would yield a gasoline of excellent octane rating. For the duration of the present European conflict, it may be assumed, however, that officials of the Soviet Union charged with supplying gasoline for the military establishment as well as for meeting the requirements of the civil population, will no doubt concentrate largely on extending the capacity of plants using tested and time-proved distillation, and cracking methods.

Incomplete reports from abroad refer to the construction of a 4,800 bbl. per day atmospheric and vacuum topping unit together with a 1,350 bbl. per day rerun unit and a 1,200 bbl. per day stabilizer in India. Construction of these units was completed early in 1940 and the plants are now on stream. During the past year, a benzol-ketone de-waxing plant was also constructed in India and is now in operation. At present a propane recovery unit is under construction in that country.

In Netherland India, one vacuum lubricating oil rerun unit was completed early in 1940.

In France during the early part of this year, construction was halted about half-way along on four plants for aviation gasoline production including iso-pentane, hydrogenation for iso octane, selective polymerization for iso octane and feed preparation units.

In England, one complete lubricating oil refinery was completed and started up in the first half of this year. A number of cracking and distillation units were under construction recently and have now been put on stream or soon will be.

In Japan, a complete lubricating oil plant including vacuum distillation, benzol-ketone, dewaxing, furfural refining and contact filtration was constructed and is probably now in operation.

In South America, the small refinery of the South American Gulf Oil Company on the Barco Concession was completed and put on stream about eleven months ago in accordance with the stipulation of the concession-contract.

In Argentina, a 2,000 bbl. per day combination, topping and cracking unit, a 3,500 bbl. per day combination, topping and cracking unit, and a 5,000 bbl. per day visbreaker were constructed during the current year.

In Peru, a complete refinery with topping was completed during 1940.

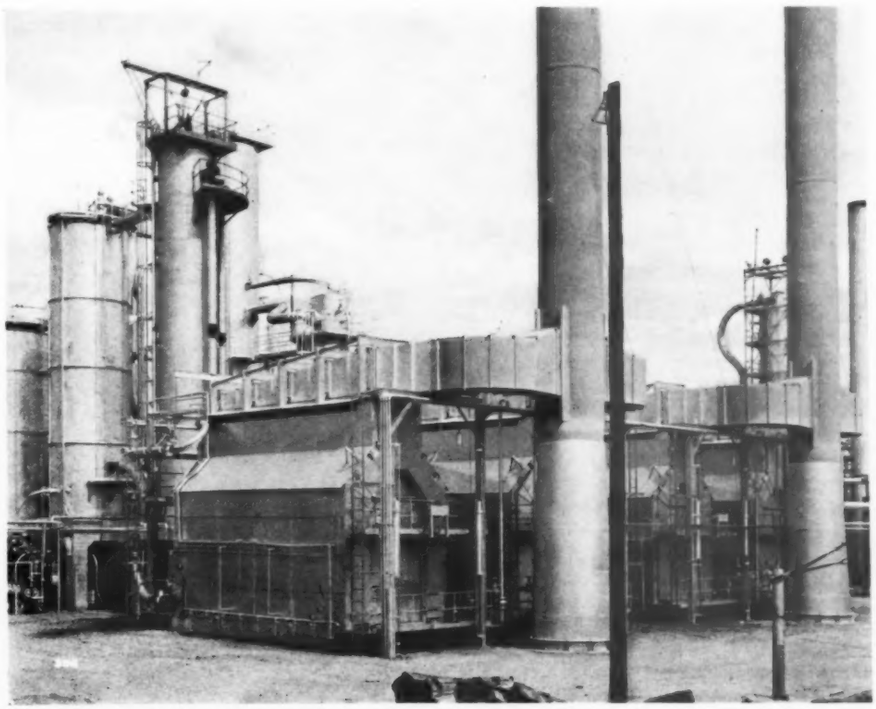
In the United States as in the rest of the world, the European and Far Eastern wars have had a profound influence on refinery construction, modernization, and the types of processes towards which the refining industry has turned its attention.

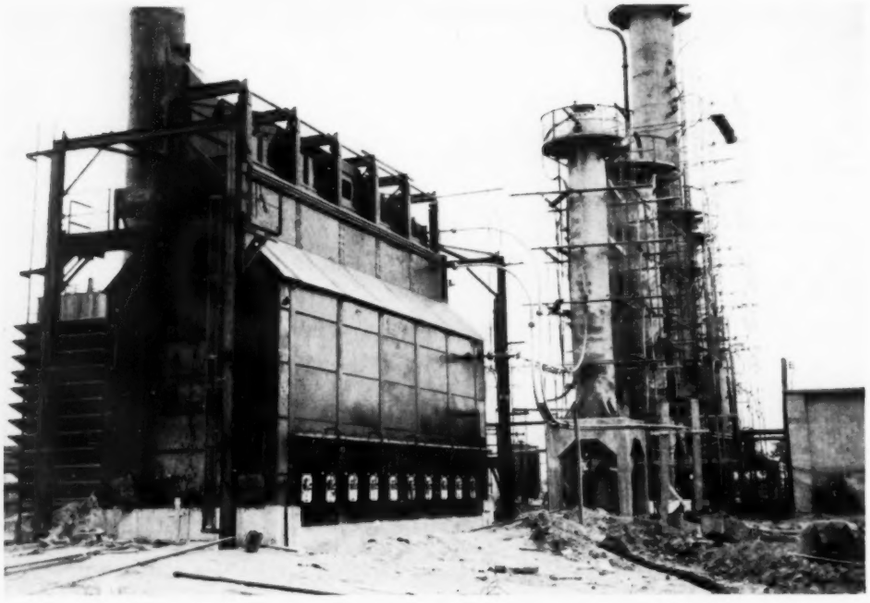
For the first time in four years, the actual number of refineries in the United States showed an increase as of January 1, 1939 compared with January 1, 1938 according to a report of the Bureau of Mines. This report indicates a total of 547 refineries in the United States of which 461 were operating.

Numerous consultations have been held by members of the National Defense Advisory Commission with members of the oil refining industry with a view to securing strategically located refining capacity and to assure adequate supplies of the specialized products that would be required in the event of war. As yet however, very little of this construction has actually got underway, due partly to the fact that the U. S. refining industry was in a position to furnish quantities and types of products such as would be required in the event of war, without dislocation of normal operations, and due also to the necessity for very careful planning in respect to such construction as it would be necessary to undertake. It is not to be expected that much of the modernization and extension work that will be undertaken by the industry in collaboration with the National Defense Advisory Commission and the War and Navy Departments, will be underway before the spring of 1941.

Two types of plants are lacking in the United States for the production of material from petroleum that would be required in a national emergency. One of these products is tuluol, normally produced from coke-oven light oil as a by-product of steel manufacture. Such a plan is described on page 88 of this issue. It has been estimated that the commercial requirements for tuluol can be met from existing capacity for the treatment of

Two coil selective Dubbs cracking unit of the Cosden Oil Corporation at Big Spring, Texas with a rated charging capacity of 5,000 bbl. per day.





Aurora Gasoline Company's 2,000 bbl. per day Dubbs cracking unit on the River Rouge near Detroit.

coke-oven light oil. Because toluol is one of the principal ingredients of T. N. T. requirements for this product would be greatly increased in any national emergency. Calculations by officials charged with meeting defense requirements in collaboration with research workers in the petroleum industry have indicated, however, that all additional military requirements could be met by the production of tuluol from petroleum if adequate facilities were available.

In this connection it is interesting to note that the War Department recently announced a contract with the Humble Oil and Refining Company for the construction of a $10,760,000 new plant at Baytown, Texas for the production of this important product among other things. The same announcement referred to an additional $1,077,000 for the expansion of the present Humble plant at Baytown. The company will defray these costs with the usual five year amortization.

Other factors that have controlled the extent and direction of refinery construction and modernization have been the increasing domestic demand for motor fuel and the trend towards constantly higher qualities of motor and aviation fuel. These factors have been controlled and limited however by the increasing stringency of competitive conditions and the constant necessity for reducing the cost of petroleum products. Despite these limiting factors it has been estimated elsewhere in this issue that refinery construction and modernization has involved the expenditure of the gigantic sum of over $200,000,000 during the past year.

Extensions of the Houdry process have been reported. In November, the Sun Oil Company will place in operation a new Houdry twelve-case catalytic cracking unit designed for the conversion of gas oil stocks thermally cracked at the Marcus Hook plant. This company has also added a Houdry catalytic reforming process to their Marcus Hook catalytic cracking and treating unit which was reported on in the 1939 Refinery Issue of WORLD PETROLEUM. This plant is now capable of complete catalytic processing of crude oil and is the first combination unit of its kind in the United States. These additions to the Marcus Hook plant of the Sun Oil Company are referred to more fully on other pages of this issue.

In the east, the Standard Oil Company of New Jersey recently embarked on an expansion and modernization project for the company's Bayway refinery, to cost approximately $2,500,000. While not officially stated, it is expected that a part of this improvement will include the installation of the new hydro-forming process and that the work at Bayway will be at least indirectly connected with the National Defense Program.

At nearby Bayonne, New Jersey, the Tide-Water Associated Oil Company has installed a combination gasoline stabilizer and vapor recovery plant for the stabilization of 18,000 bbl. of gasoline per day. More recently Tide Water has awarded a contract to E. B. Badger and Sons Company for the construction of a Houdry catalytic refining unit at the Bayonne plant. The new unit is said to have a capacity of 15,000 bbl. per day which will be added to the existing capacity of Tide Water's Bayonne refinery previously amounting to 55,000 bbl. of crude oil per day and a cracking capacity of 21,000 bbl. per day.

In Philadelphia, a naphtha heater and polyform naphtha charging unit have been installed by the Lummus Company.

At Barber, N. J., the Barber Asphalt Corporation has recently revamped its Coastal cracking plant by the replacement of the old furnace with two new furnaces and is further modernizing this unit by changing it primarily from a single coil cracking unit to a combined cracking and topping unit, to operate on a once-through and recycle basis.

The Kendall Refining Company of Bradford, Pennsylvania, has added during the past year a phenol extraction plant with a capacity of 1,500 bbl. of oil per day. This unit is used for the extraction of neutrals and bright stock. The same company has recently added a Dubbs catalytic polymerization plant to their existing Dubbs cracking units. The new unit is capable of processing 1,000,000 cu. ft. of gas per day. A low vapor pressure cracked gasoline is taken from the original stabilizer and the gases are discharged under stabilizer pressure to the polymerization unit. A further addition to the Kendall plant consists of a U. O. P. copper sweetening plant for straight-run gasoline, permitting treatment as a continuous operation. Gasoline is passed through the reagent vessels on its way to storage tanks, producing a doctor sweet gasoline.

The Lummus Company has also installed an emulsion de-oiling plant at Bradford.

Aerial view of the Los Angeles harbor refinery of the Union Oil Company at Wilmington, Calif.

NEW

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Completely shop assembled for heat absorption up to 15,000,000 b.t.u.'s, per hour. Larger sizes shop prefabricated in large sections consistent with transportation facilities.

Designed and built for all phases of general refinery service including distillation, cracking, high temperature gas pyrolisis and gas plants. Also as a pipe line heater and steam superheater. *THE ISO-FLOW RADIANT FURNACE* offers for the first time a completely prefabricated unit of large size with a minimum of installation labor and a low capital investment.

THE ISO-FLOW RADIANT FURNACE has been developed for either high or low thermal efficiency and all of the *radiant* heating surface absorbs heat at the maximum permissible transfer rate and at a uniform heat intensity. The all *radiant* design for normal efficiency is readily modified to include an extended convection section or an air heater for high efficiency.

The design and features of the ISO-FLOW RADIANT FURNACE are the subject matter of application for U. S. Letters Patent.

Illustrated is an installation at a Texas Recycling Plant handling 10,000 bbl. per day. This unit went on stream 81 days after receipt of order and immediately operated at 25% over designed capacity.

FIVE completely shop assembled ISO-FLOW RADIANT FURNACES are now in fabrication for installation in the Far East.

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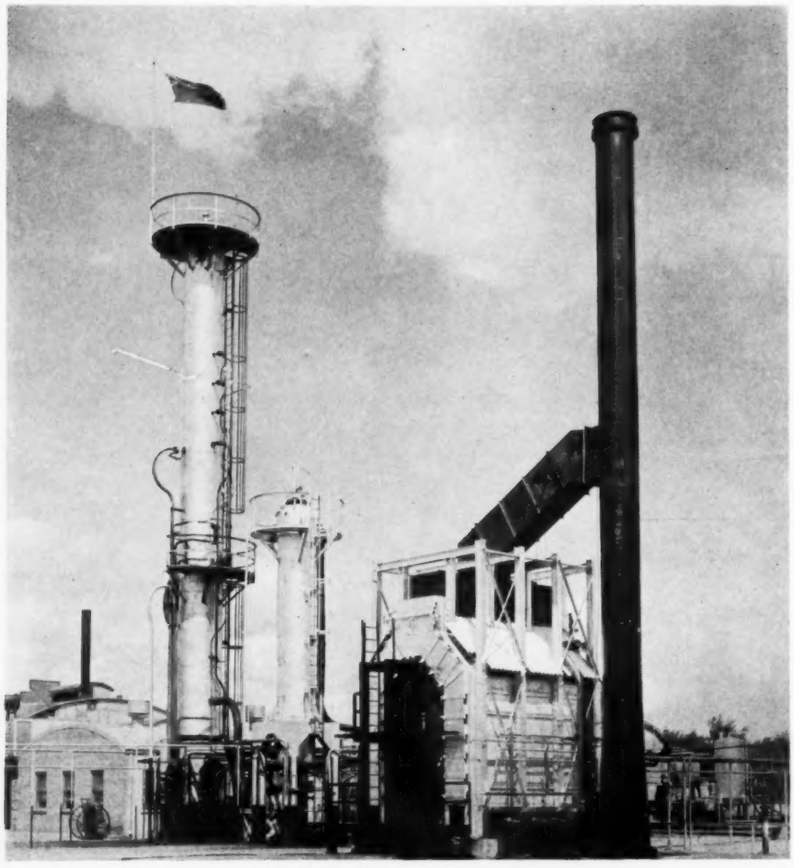


Single coil Dubbs unit at Brandan, Canada.

Pennsylvania of the type that is described in detail on other pages of this issue.

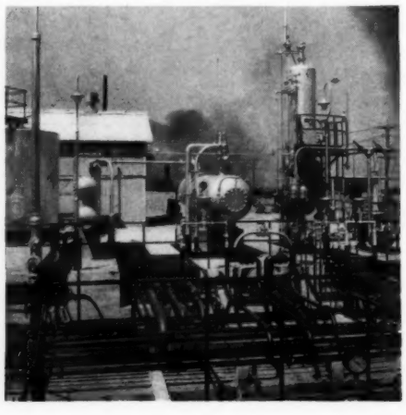
Elsewhere in Pennsylvania, the Quaker State Oil Refining Corporation has made additions to the boiler plant at their Farmers Valley refinery, consisting of a 65,000 lb. steam generator using pulversized coal. At the Emlenton plant of this company, a 45,000 lb. steam generator of the same type was installed. Quaker State has also revamped the cracking facilities at the Emlenton plant and has installed additional reforming coils and polymerization equipment at their refinery at St. Mary's, West Virginia. In addition solvent extraction plants have been completed at St. Mary's and at Farmers Valley.

Standard Oil Company of Ohio recently started construction of a catalytic polymerization unit at its Cleveland plant, as a part of a $1,000,000 construction program, which has been announced for the Cleveland, Lima and Laconia refineries. At Canton, Ohio, the Canton Refining Company has increased its cracking capacity by the installation of a Dubbs unit. The Worth Refining Company recently began operation of a 2,000 bbl. per day cracking plant at Blue Island, Illinois.

In Kentucky, the Ashland Oil and Refining Company has undertaken expansion of its distillation plant to increase the capacity by 2,500 bbl. per day. Additions are being made to the steam generating and storage plant and the program calls for construction of a new vacuum flash unit for the production of asphalt. In Louisville, the Aetna Oil Service Incorporated has spent during the past year $100,000 on improvements to their cracking unit and on the erection of a new gasoline stabilizer and a continuous gasoline treater in connection with their 8,500 bbl. skimming and cracking plant.

In Detroit, Michigan, the Aurora Gasoline Company, recently completed construction of a 2,000 bbl. per day Dubbs cracking unit located at Detroit with marine facilities on the River Rouge and connected with the Buckeye Pipeline. The Aurora Gasoline Company now operates two skimming plants, one at Detroit having a capacity of 4,000 bbl. per day of Illinois crude; the other is located at Elsie, Michigan, processing 3,000 bbl. per day of Michigan crude. At Alma, Michigan, Mid-West Refineries, Incorporated, which recently acquired two plants of the Imperial Refining Company at Grandville, Michigan has begun the installation of a two-coil selective Dubbs cracking unit for 2,000 bbl. per day of topped Michigan crude. The Essex Refining Company has recently completed construction of an 1,800 bbl. refinery at Essexville, Michigan to treat crude oil from the Wisner field in Tuscola county. At Muskegon, Michigan, the Naph Sol Refining Company has installed a polymerization plant as has the Old Dutch Refining Company of the same city.

Union's alkylation unit at the Wilmington refinery.



Across the border, in Canada, the Imperial Oil, Ltd. has recently let a contract for construction of a new coking plant in connection with its Sarnia refinery. An announcement was made earlier in the year that the Gas and Oil Products, Ltd. contemplated the addition of high-octane equipment to its present refinery in the Turner Valley field. Due to the increased demand for gasoline with octane numbers of the order of 95 to 100, for modern bombers and fighting planes, the company had been making an investigation of the possibilities of adding to their plant. Another refinery operating on Turner Valley crude was completed during September. This is the 2,000 bbl. plant of the North Star Oil, Ltd., being constructed near St. Boniface.

At Petrolia, Ontario, the Canadian Oil Company, Ltd., is engaged in remodelling its present topping and cracking units by the addition of a Dubbs unit, to increase the capacity of their plant to 1,300 bbl. per day of topped crude. A catalytic polymerization unit for the production of polymer gasoline from the cracked gases will also be added to the refinery.

At Kalistell, Montana, the Unity Petroleum Corporation revamped its plant early this year, increasing the capacity from 800 to 1,100 bbl. per day, and adding a tetraethyl lead blending plant. Production Refining Corporation recently completed a 1,500 bbl. per day topping plant and a new tetraethyl lead blending plant as well as the addition of 14,000 bbl. of crude oil storage space.

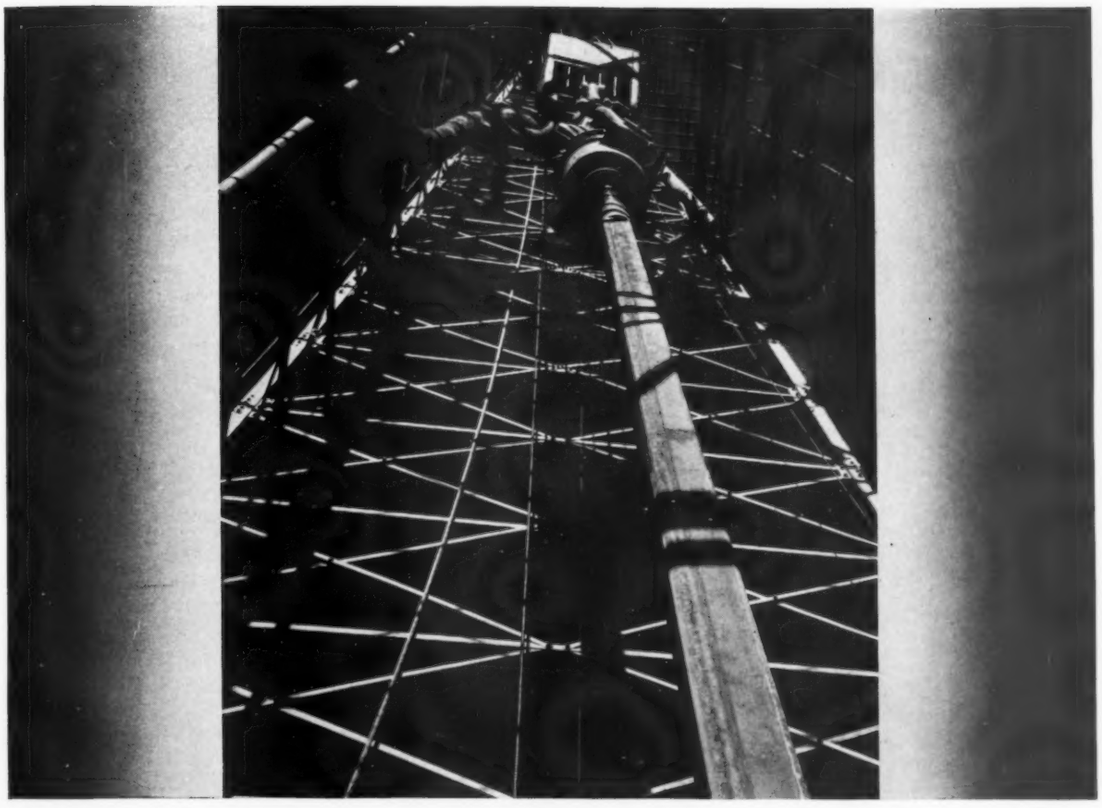
The Wisconsin Oil Refinery Company started construction in July on a 5,000 bbl. per day skimming plant at Sheboygan, Wisconsin. It has been announced that the company expects to add a cracking unit at a later date.

At the Casper, Wyoming refinery of The Texas Company, a catalytic polymerization unit is being installed at an expenditure of approximately $100,000.

Early in 1940, the completion of the Alamosa, Colorado refinery of the Gramps Oil and Refining Corporation was announced. The plant consists of a topping unit with 1,000 bbl. per day capacity and a two-coil Dubbs unit of 700 bbl. per day capacity.

Announcement has been made of the construction soon to be undertaken of a 2,000 bbl. per day topping plant at Falls City, Nebraska

(Continued on page 108)



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By J. C. Groff

Aldrich Pump Company

DEVELOPMENT of modern petroleum refining, polymerization and other chemical processes necessarily involve the pumping of fluids at controllable rates against pressures of considerable magnitude. The cost-reducing need for economical power consumption dictates the use of the highly efficient reciprocating plunger pump for such pressures, particularly when the volumes pumped are not sufficiently great to obtain acceptable efficiencies with centrifugal pumps.

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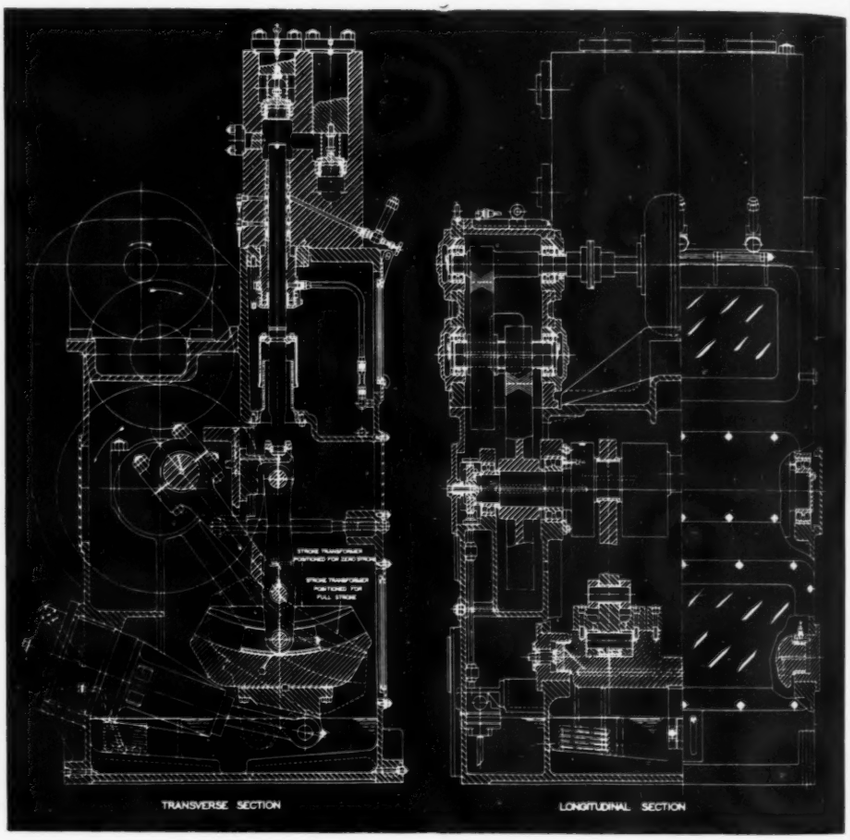
This new pump is of the reciprocating plunger type built in a vertical triplex arrangement and embodying simple but reliable mechanism for controlling the plunger stroke and, thereby, the pump delivery from zero to a rated maximum output.

As shown in the cross-sectional drawings, this triplex pump is driven by a constant speed motor through double-reduction gearing. A connecting-rod from each of the three crankpins serves to oscillate a link about its point of attachment to a conventional crosshead at its upper end. Pivotally attached to the lower end of each link is a bronze guide block which slides back-and-forth in a curved track on the "stroke transformer". The radius of curvature of this track is the same as the distance between it and the center of the cross-head pin.

The stroke-transformer is arranged for tiltable adjustment about its longitudinal axis under control from a 4-way oil pilot valve, which serves to position a double-acting "servo-piston" connected to the bracket on the underside of the transformer by a link.

When the transformer occupies the position indicated by solid lines, the center of curvature of the tracks coincides with the center of the crosshead pin and no movement is imparted to the plungers even through the crankshaft continues to rotate.

The maximum designed stroke of the plunger is achieved when the transformer is tilted into the position indicated by dashed lines. Control of this positioning and of the rate of pump delivery is by means of an air-operated diaphragm head of conventional type which is connected to the 4-way oil valve. This diaphragm head is, in turn, operated by control air from any standard automatic regulator or controller of the air-pilot type.



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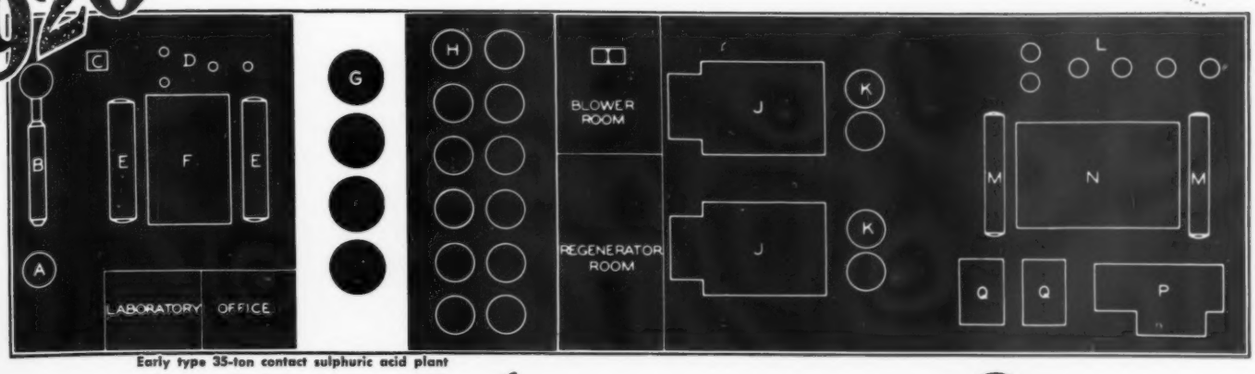

Early type 35-ton contact sulphuric acid plant

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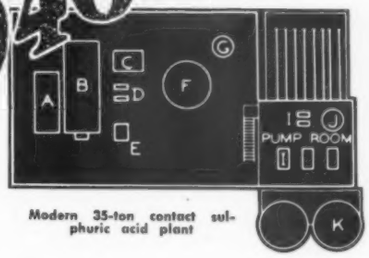

Modern 35-ton contact sulphuric acid plant

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IN the two diagrams shown above, drawn to the same scale, each circle and rectangle represents apparatus used in a typical contact sulphuric acid plant in 1920 and in 1940. Notice the sharp contrast . . . in the amount of equipment required . . . in ground space occupied.

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"Radically new in design and proven in practice" is a fitting term for the Aldrich-Groff controllable capacity pump designed for such severe services as handling butane and propane at high pressures. One of these pumps has been in service at the Montreal Refinery of the Shell Oil Co. of Canada Ltd. for over six months where its operation has been entirely satisfactory handling butane-propane mixture against discharge pressures of 1,150 to 1,400 P.S.I. with suction pressures of 175-200 P.S.I. No difficulties—say Shell engineers—have been experienced in achieving controllable delivery between zero and the rated maximum capacity of 40 G.P.M. Its automatic stroke control system—operated by pilot air through a pressure range of 2 to 15# — has been effective in taking care of fluctuations in feed rate demands.

Let us send you complete details and drawings of this remarkable new achievement in oil industry pump engineering, or have our sales engineers call.

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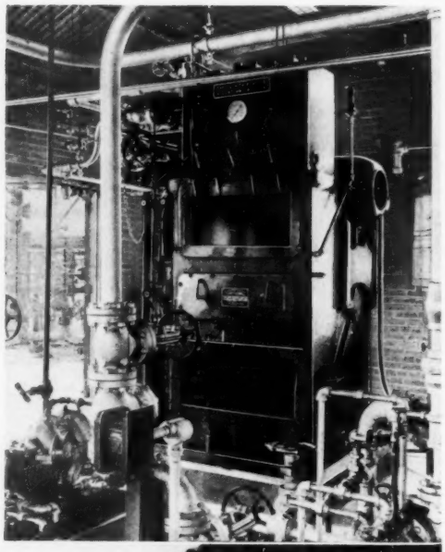

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(Continued from page 104)

to which later will be added the cracking equipment.

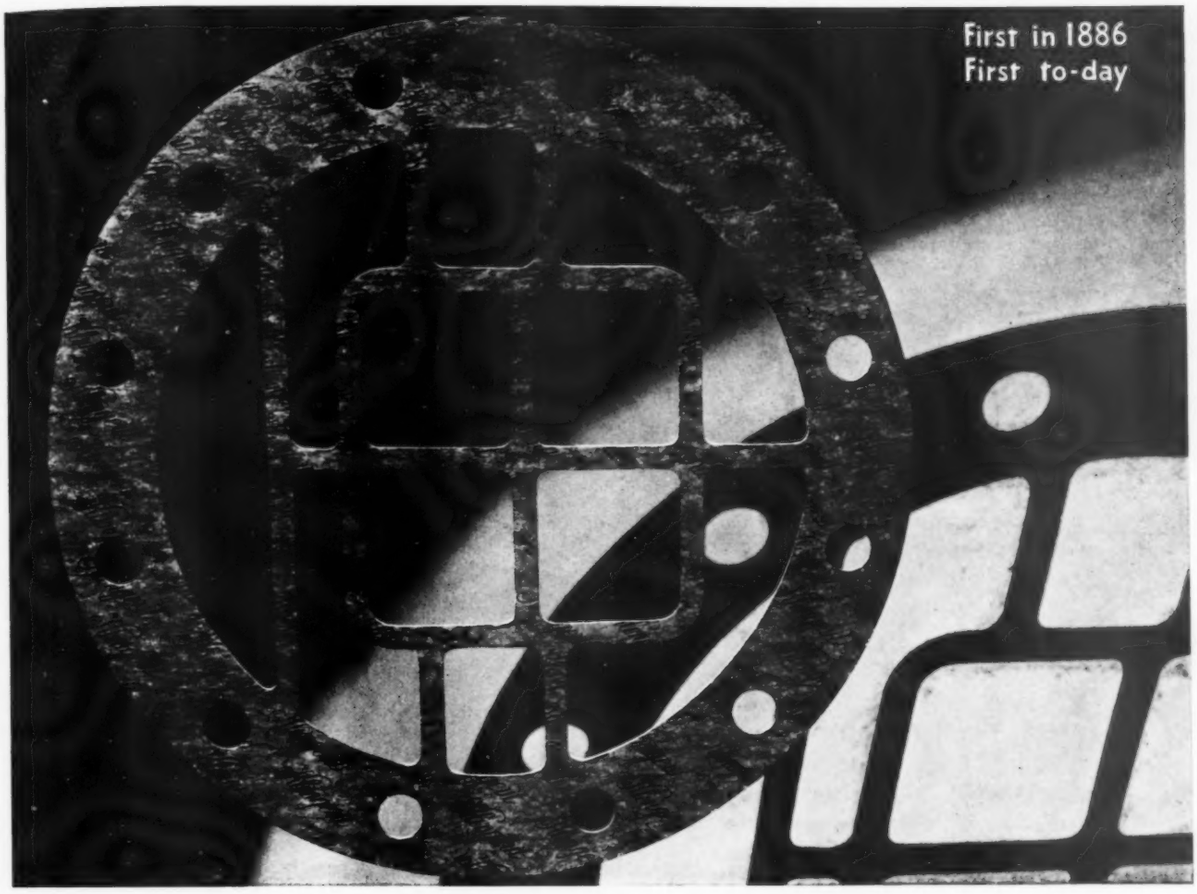
This report from Curtis Flint of Hayne California coincides with a report from R. D. Swan of Joliet, Illinois that the Mid-State Refining Company had acquired a 2,500 bbl. refinery which it was the intention of his company to dismantle and transport for erection to Falls City, Nebraska.

In Kansas, the Bareco Oil Company is adding a new 2,500 bbl. per day skimming unit to its Wichita, Kansas refinery. On January 1 of this year, the new 3,000 bbl. per day refinery of the Cooperative Refinery Association came on stream. Reconstruction work has also been announced by Skelly Oil Company for its El Dorado, Kansas refinery. Additional gasoline recovery equipment will be added and the two existing cracking units will be remodeled at a cost of approximately $250,000. Present capacity of the El Dorado refinery is in the neighborhood of 23,000 bbl. per day. A 2,500 bbl. per day, copper sweetening unit is being added to the Derby Oil Company refinery at Wichita.

In Oklahoma, the Mid-Continent Petroleum Corporation has installed a new Lummus emulsion de-oiling wax process, the type described in detail elsewhere in this issue. The Mid-Continent has completed a program calling for the installation of considerable modern refining equipment in its Tulsa refinery.

In Texas, the Danciger Oil and Refining Inc. is installing a two-coil selective type residuum flashing Dubbs unit, with stabilizer and absorber. Improvements to this plant also include the construction of a U. O. P. catalytic polymerization unit. The Dubbs cracking and reforming processes replace an existing cracking unit at the Pampa, Texas plant of Danciger. Independent Refining Company is building absorber and stabilizer equipment and a catalytic polymerization unit at their Arp Texas refinery. Pure Oil is installing a Gray clay treating process at its Smiths Bluff, Texas refinery. The unit is designed to treat polymer gasoline for the removal of gum-forming material. Phoenix Refining Company started construction of a 2,000 bbl. refinery in Houston county in July of this year. Also in July, the thermal polymerization unit that has been constructed at the Wichita Falls, Texas refinery of the Continental Oil Company came on stream. The new unit which cost in the neighborhood of $750,000 is expected to produce a minimum of 500 bbl. of high octane polymer gasoline daily. Magnolia Petroleum Company has started work on its Fort Worth refinery for the addition of a new combination unit and polymerization plant. Existing equipment will be modernized and the total capacity of the revamped plant is expected to reach 20,000 bbl. per day. The Levelland, Texas plant of Motor Fuel Corporation has been modernized to increase its capacity from 3,500 to 5,000 bbl. per day at a cost of approximately $100,000.

At Lake Charles, Louisiana an entirely new



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plant is under construction for Continental Oil Company at West Lake, three miles from Lake Charles. The 10,000 bbl. per day refinery consists of a combination unit with crude topping, casinghead-gasoline stabilization, cracking, reforming, alkylation and polymerization.

In Arkansas, the Lion Refining Company has increased the capacity of its El Dorado refinery and has added a new Lummus combination gas-oil cracking and reforming furnace.

In California, the Union Oil Company has added a phenol treating plant to augment the facilities for the manufacture of solvent process lubricating oil at its Oleum Refinery. The company has also completed construction of an alkylation plant at its Wilmington refinery for the production of 100 octane aviation gasoline. A polymerization plant has been added to the Oleum refinery. More recently, construction has been commenced on coking and hydroformer plants for the manufacture of high octane cracked gasoline and on an asphalt tubular still plant, at Oleum. Union has also performed a considerable amount of work in modernizing and expanding refining facilities both at the Wilmington and the Oleum refineries. A two-coil selective Dubbs cracking unit with crude distillation equipment is being built by Douglas Oil and Refining Company in Los Angeles county, designed by Universal Oil Products engineers. The plant is being constructed by the Fluor Corporation of Los Angeles. Richfield Oil Corporation has installed an alkylation unit at its Watson refinery in Los Angeles county. This work was also performed by the Fluor Corporation and with other minor modernization work at this plant is reported to cost in the neighborhood of $700,000. Rothchild Oil Company is installing adjacent to its 3,000 bbl. per day skimming plant, a Dubbs cracking unit and a U. O. P. catalytic polymerization unit. The two-coil cracking unit will have a capacity of 2,200 bbl. per day and the catalytic polymerization unit will handle 500,000 cu. ft. of cracked gas per day for production of 82-84 octane polymer gasoline. Another Dubbs catalytic polymerization unit with a capacity of 345,000 cu. ft. of gas per day, is being installed by Pathfinder Petroleum Company at its Los Alamitos Refinery.

While the foregoing is only a partial list of the new construction, modernization and remodelling that has taken place in the United States during the past year, it is sufficient to indicate that the demand for higher octane motor fuel, for high pressure lubricants, and for aromatic products for possible use in national defense have combined with the availability of a number of new thermal and catalytic processes to produce a considerable amount of activity in building on the part of U. S. refiners. With the anticipated increase in commercial demand for petroleum and as soon as the government program for production of specialized products of a military nature becomes more clear, it may be expected that a substantial increase in refinery construction and modernization will be witnessed during the coming year.